Pinal Model 2019 Update

November 1, 2019

If you are on the webinar, have Webex call you for audio

Place microphones on mute

This meeting will be recorded

At the end of the meeting we will take questions

If you have a question please send Jennifer Marteniez a message in Webex

Pinal Model 2019 Update

November 1, 2019

Tom Buschatzke, Director

Keith Nelson, Groundwater Modeling Supervisor

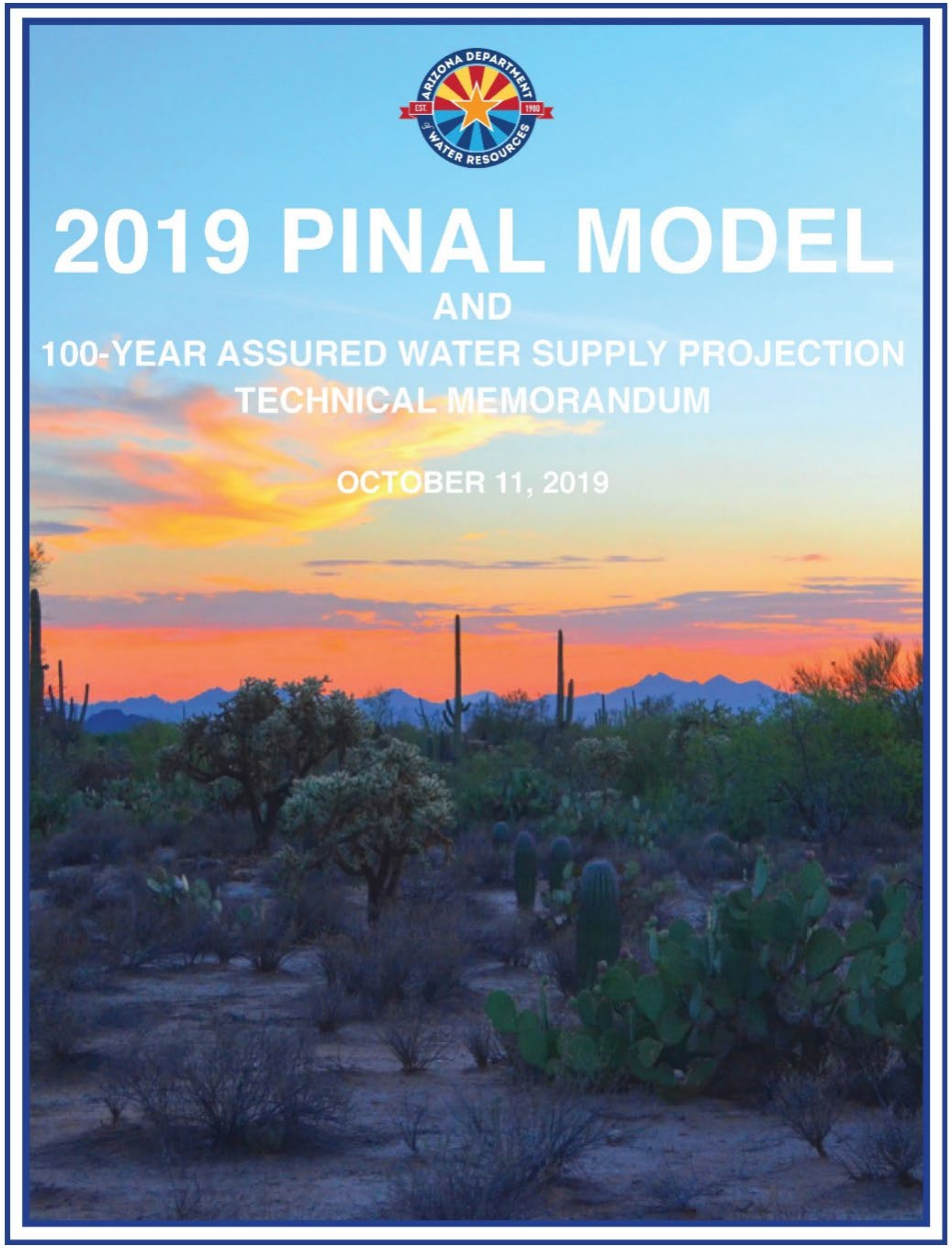
Jeff Inwood, Chief Hydrologist

Arizona Department of Water Resources

Agenda

1. **Welcome and Introduction**
   - ADWR Director Tom Buschatzke
2. **2019 Pinal Model Update**
   - Keith Nelson, ADWR Groundwater Modeling Supervisor
3. **100-Year Assured Water Supply Results in the Pinal AMA**
   - Jeff Inwood, ADWR Chief Hydrologist
4. **Next Steps**
   - ADWR Director Tom Buschatzke
5. **Questions**
   - Moderated by ADWR Director Tom Buschatzke

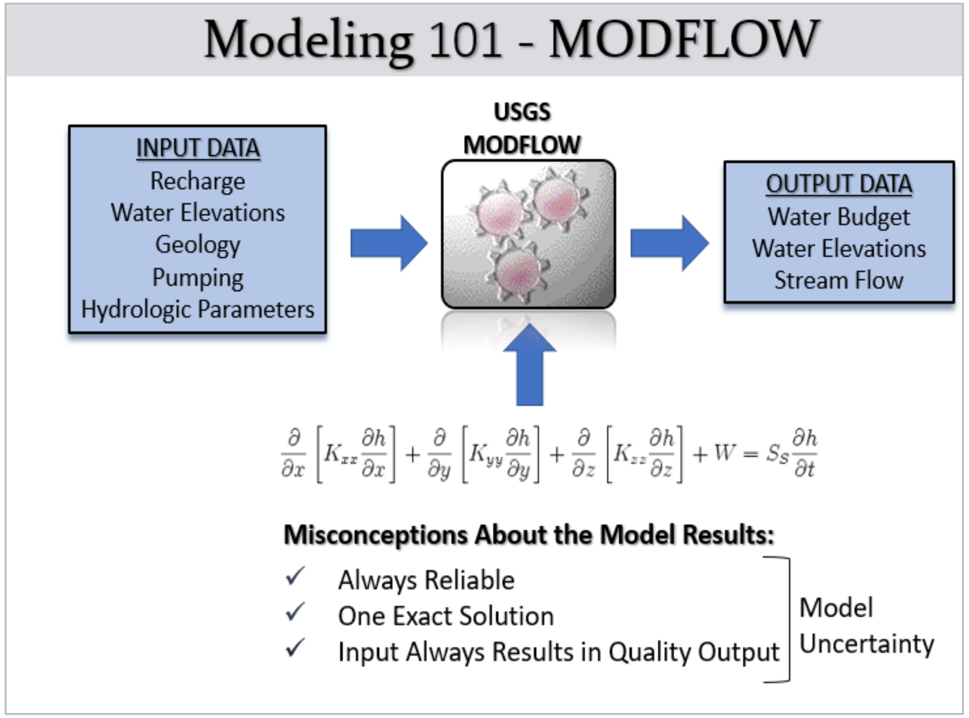
2019 Pinal Model Update



New 2019 Model

ADWR's Technical Memorandum & Model Files Released

Step #1:

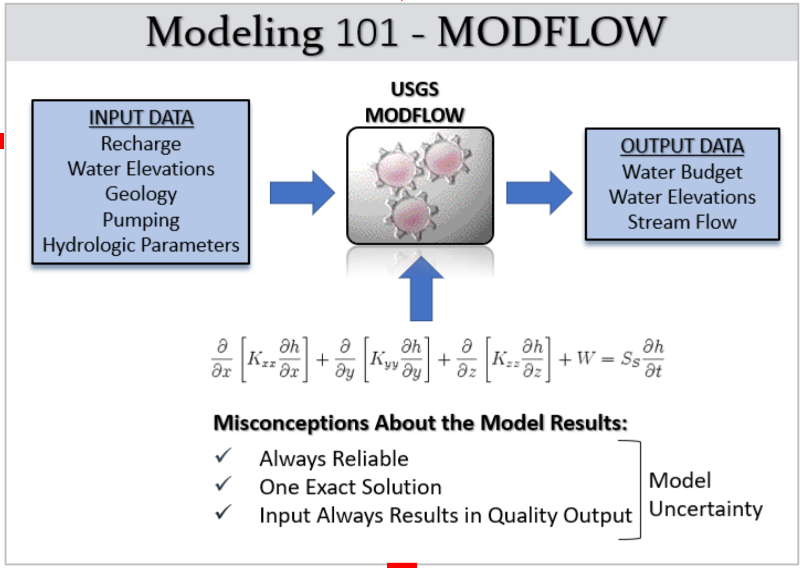


Calibrated to Historical Data: Pinal 1923 - 2015
Inverse Model Stats -> calibration byproducts for transparency – see Appendix D and SSPA Report

Step #2 *(only after #1 is complete)*

Projection Assumptions

(NOT the MODEL!!)



Step #3

Projected Model Solution

ADWR's Modeling Procedures & Model Applications

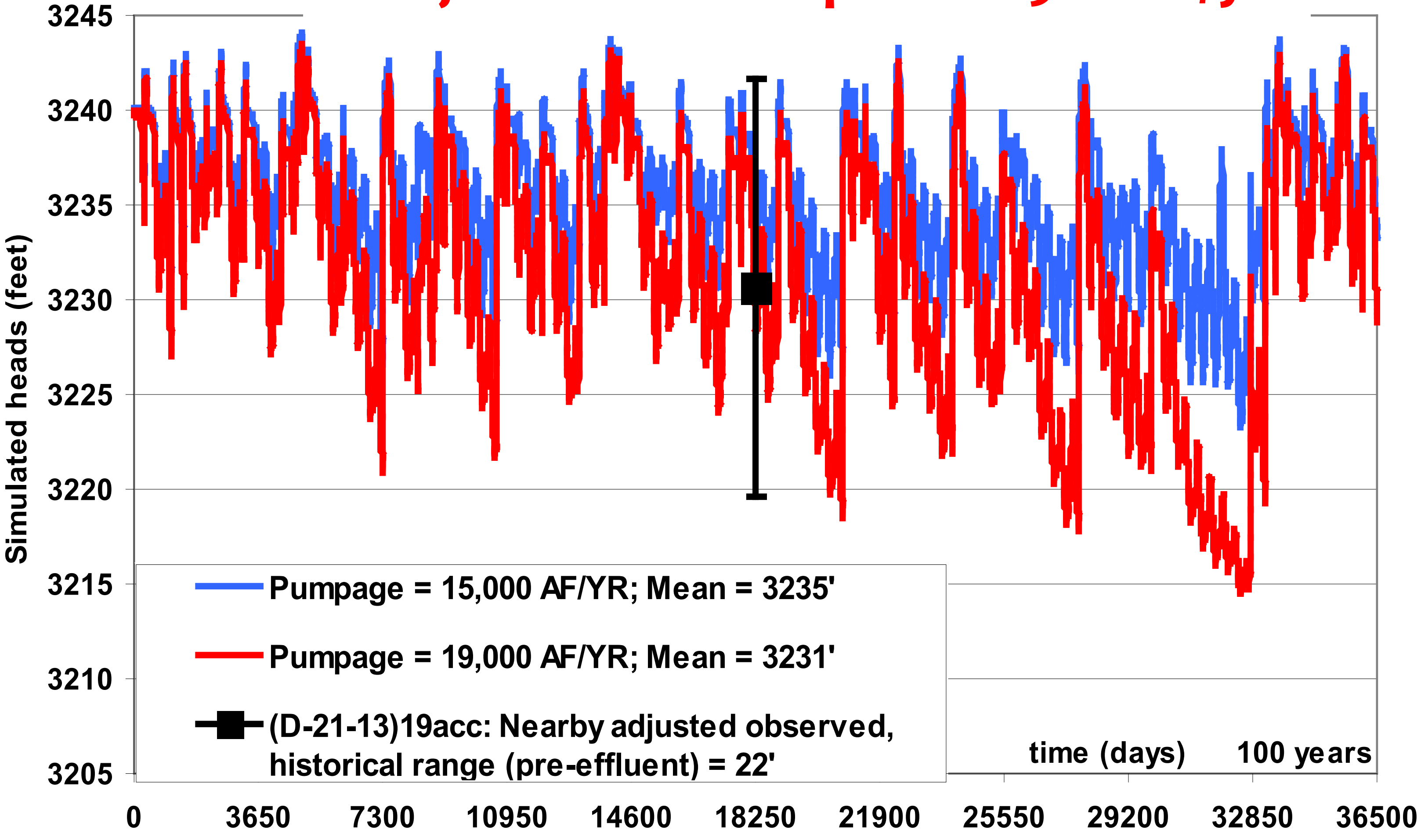
- **Develop model to better understand *Regional* groundwater flow solution;**
  1. Based on available data: non-linear regression -> data drives solution(s)
  2. Develop alternative conceptual models (ACMs)
     - Test for plausibility (or non-plausibility); parameter sensitivity
  3. List assumptions; quantify uncertainty; discuss model and parameter reliability
     - See Appendix D (Tech memo, October 2019) and SSPA Report (2016)

- **Use model as a projection tool**
  1. Explore water management strategies; (Assumptions test strategy with the model …strategies are **NOT THE MODEL!**)
  2. List Modeling Projection Assumptions (projection natural terms)
  3. Program requirement / assumptions **(NOT a MODEL!)**

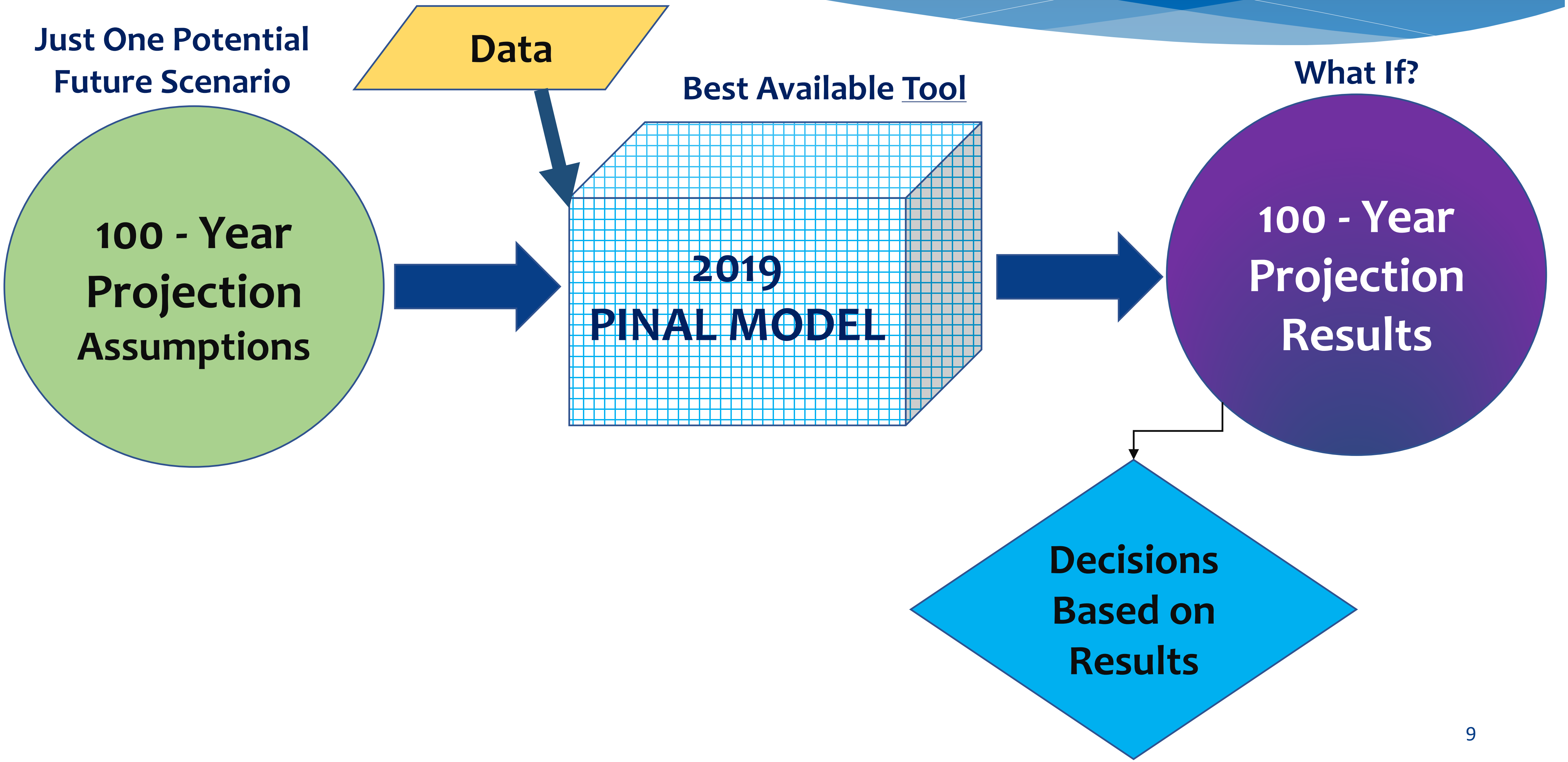
- **Support regulatory decision-making;**
  - Permitting (AWS; Recharge Program; well spacing; transport, etc.)

Projection assumption: 15 K AF/yr
Projection assumption: 19 K AF/yr

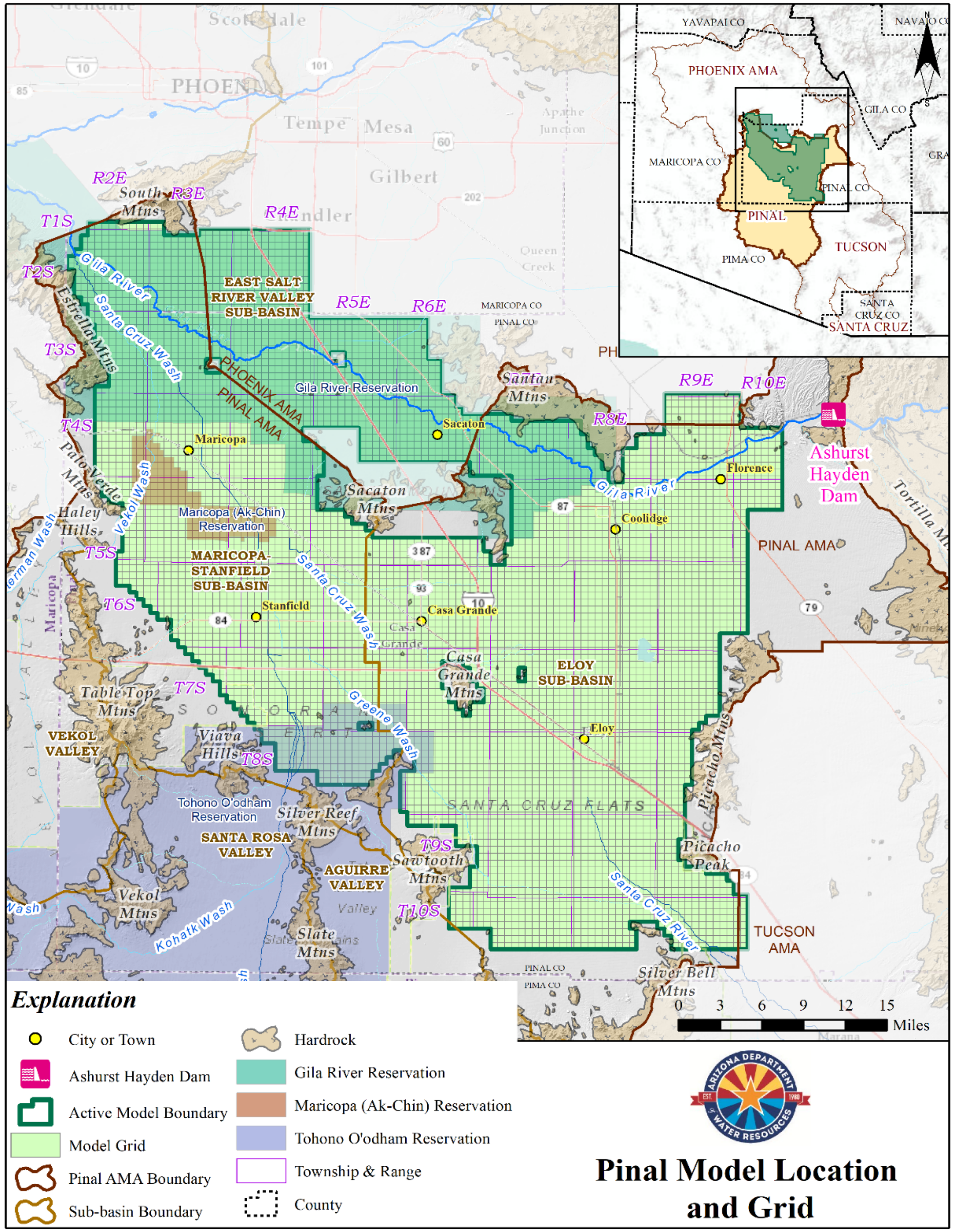
Different projection assumptions using the same "Model," all else equal



Model Projection Assumptions Are Input into the Base Model & Results are Produced



- **ADWR Models are regional scale and are used to evaluate current conditions and simulate possible future scenarios**
- **History of Pinal AMA Model**
  - 1990 2 Layer Model
  - 2014 Steady-State and 1923 – 2009 Transient
    - Significant Internal Review
    - Three External Peer Reviews
  - 2019 Steady State and 1923 – 2015
    - Appended Data 2010 – 2015
    - Other Modflow Package Improvements
    - Structural Modifications
    - Currently best available tool



Peer Review of 2014 Steady-State & 1923 – 2009 Transient Model

Two peer reviews completed during the Review of the Draft Report (2013)

1. USGS: Stan Leake and Don Pool, Hydrologists
2. U of A: Dr. Edward Martin, Agricultural Engineer

One Review completed after the Final Report (December 2016)

3. S.S. Papadopulos & Associates Inc. (SSPA): Dr. Matt Tonkin

- *"The current model structure is adequate for the current model objectives, focusing on regional and sub-regional water budgets and long-term predictions of storage depletion and water level declines over fairly broad areas."*

External Peer Review:

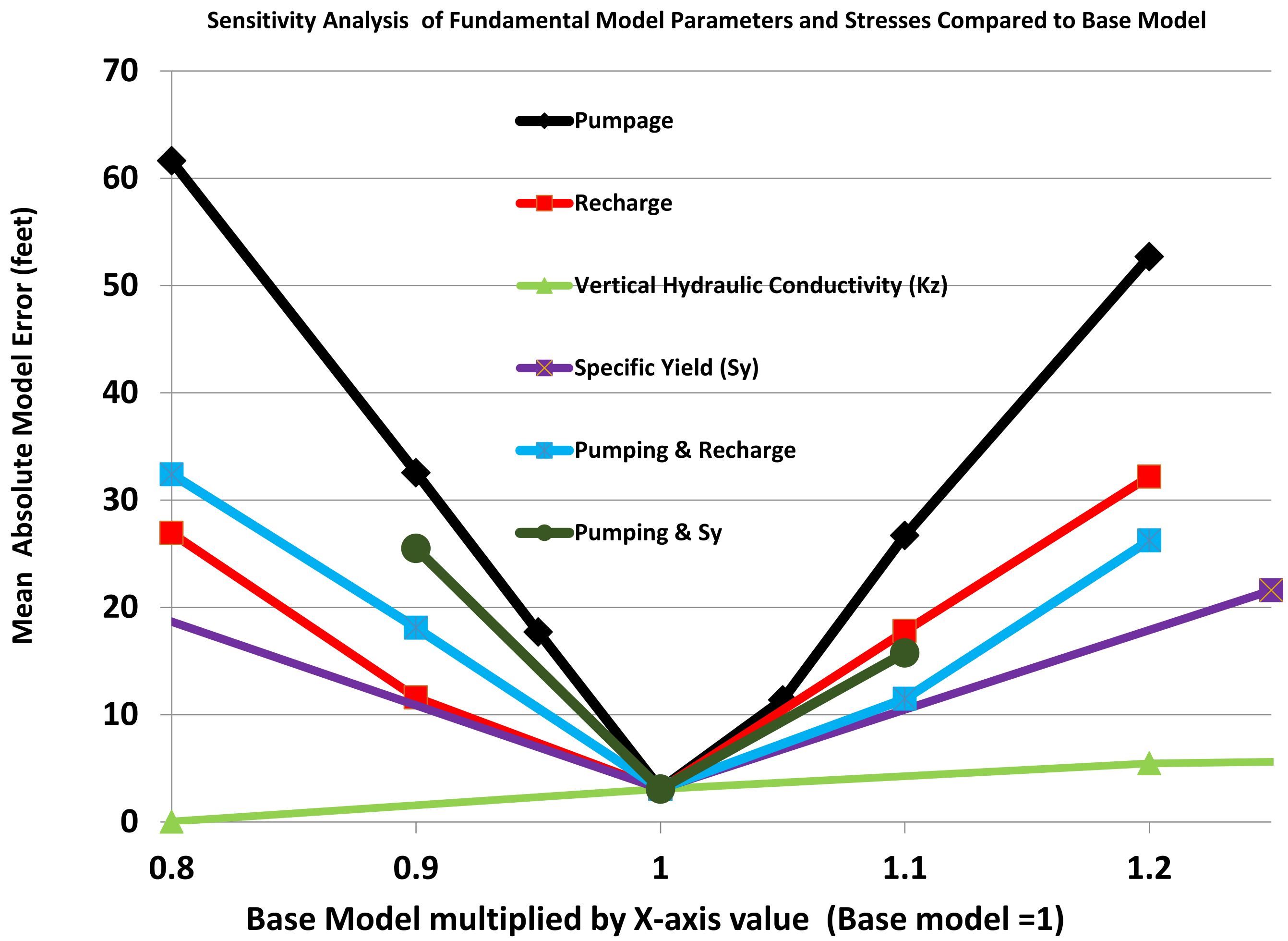
Groundwater Flow Model of the Pinal AMA, with Demonstrative Calibration and Uncertainty Analysis Procedures and Outputs

S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

December 13, 2016

7944 Wisconsin Avenue, Bethesda, Maryland 20814-3620 • (301) 718-8900

Model Sensitivity & Calibration



- **Manual Sensitivity Conducted on the 2014 Model**
  - Using head target residuals (Observed – Simulated heads)
  - Global multipliers applied to the main parameters and inputs
  - Indicated that the trial and error calibrated model had the lowest mean absolute residual error

Modifications to the Pinal AMA Groundwater Flow Model

Since publication of the 2014 Pinal model update (Liu, et.al, 2014) several updates and improvements have been made, including:

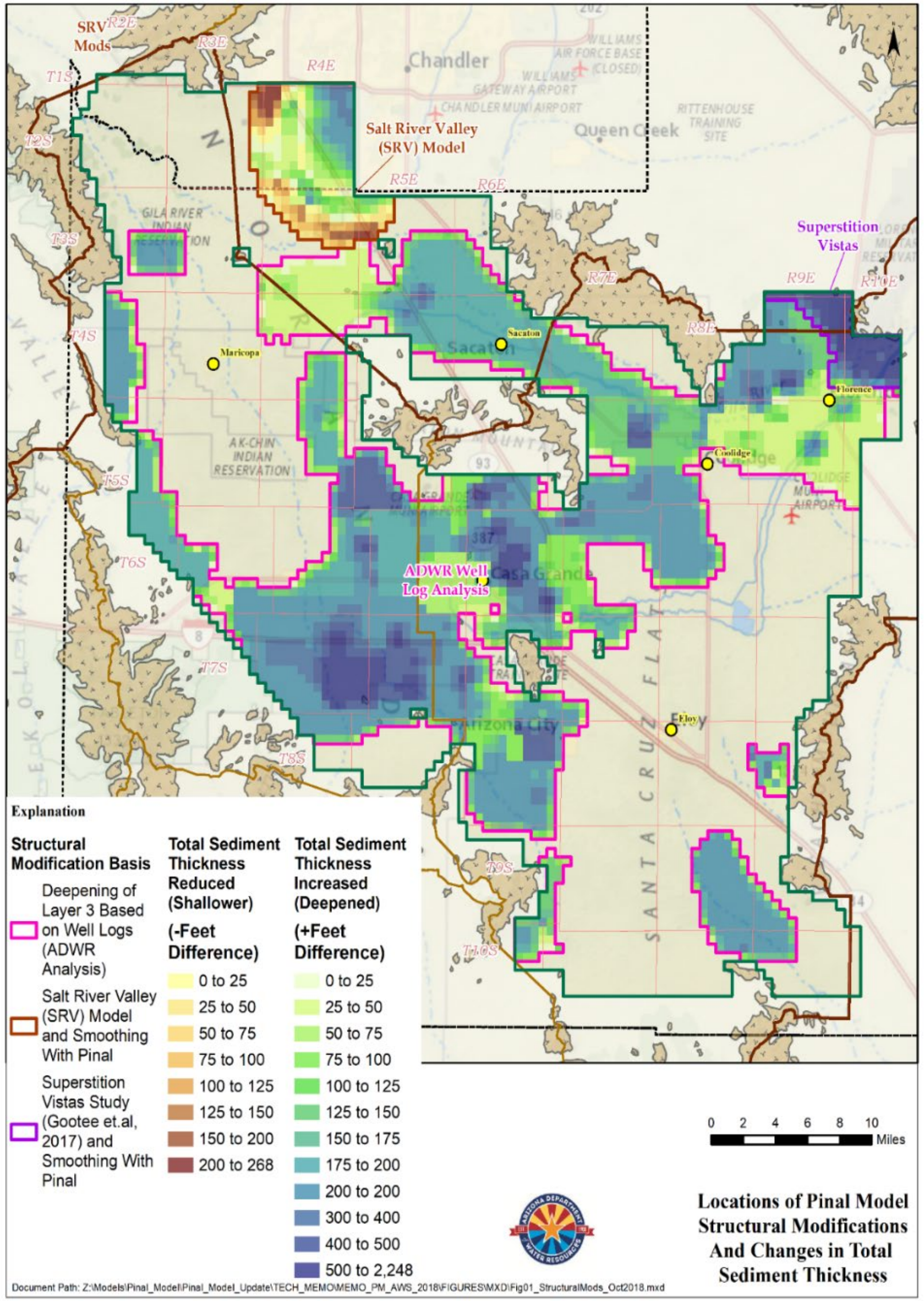
1. Updated pumping information 2010 – 2015
2. Updated recharge estimates 2010 -2015
3. Improvements to the Numerical Solver (GMG) Settings and Layer Property Flow (LPF) packages in Modflow.
4. Revisions to the Central Arizona Model (CAM) grid
5. More comprehensive head targets and use of the head observation (HOB) package
6. Boundary conditions from specified head to specified flux

* Appendix A of the Tech Memo provides more details on these modifications

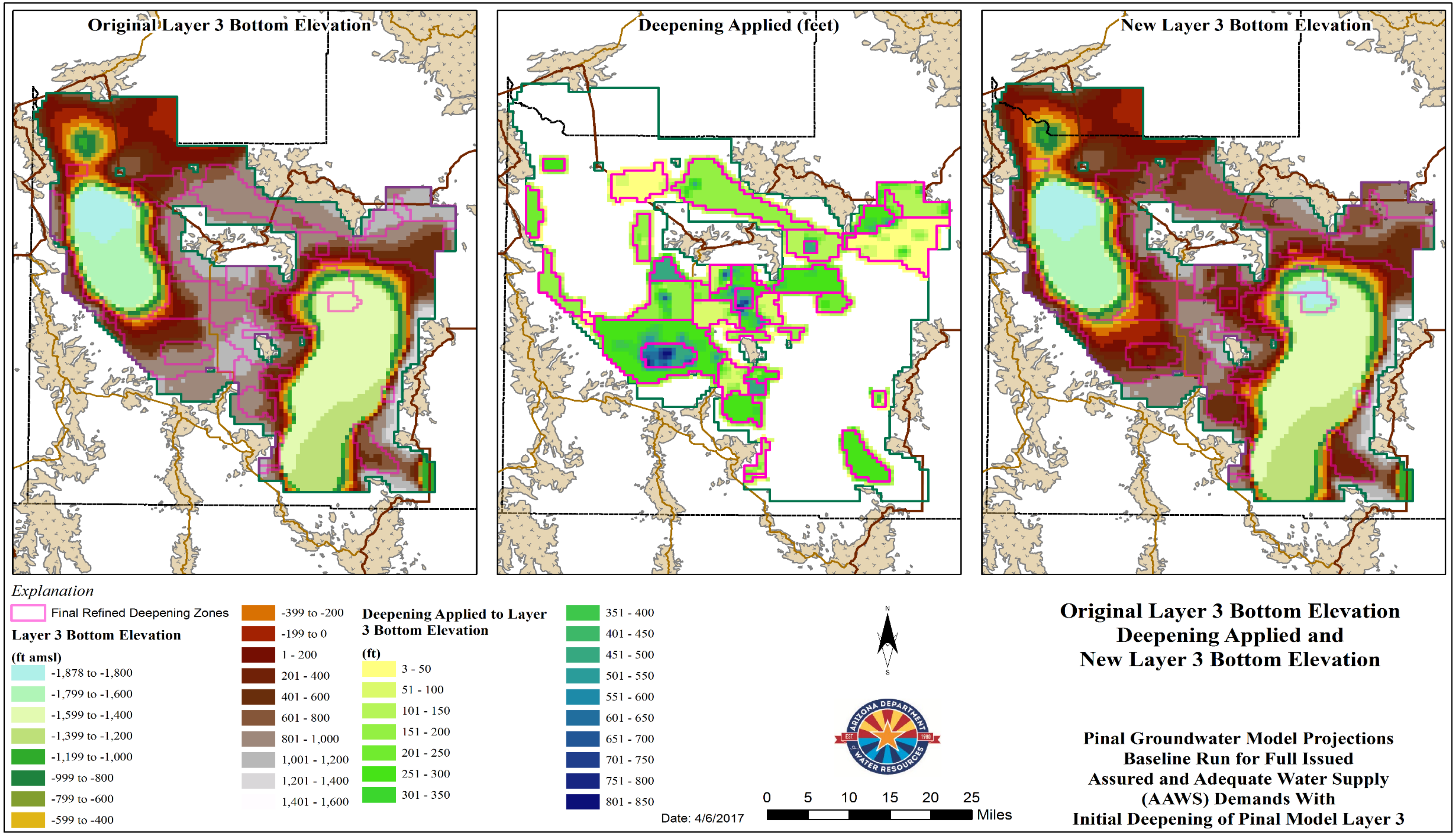
Modifications to the Pinal AMA Groundwater Flow Model

7. Structural modifications to the model geology, increasing model thickness in several areas

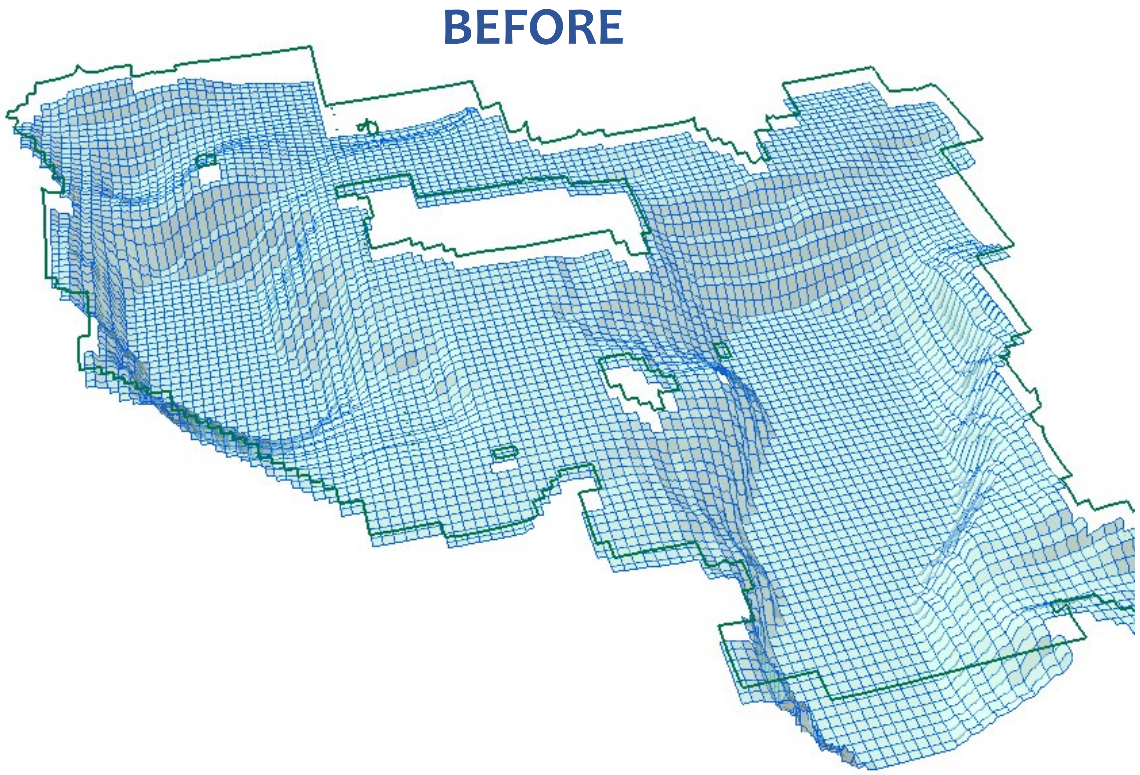
- Increased sediment thickness in areas where numerous water-producing wells were drilled below the bottom of the 2014 Pinal model.
- Further increased sediment thickness in the Superstition Vistas Planning Area north of Florence based on a joint geologic study conducted by Salt River Project (SRP) and the Arizona Geological Survey (AZGS).
- Modified model layer bottom elevations to be consistent with the SRV/Phoenix model in part of the GRIC area where the two CAM-based models overlap.

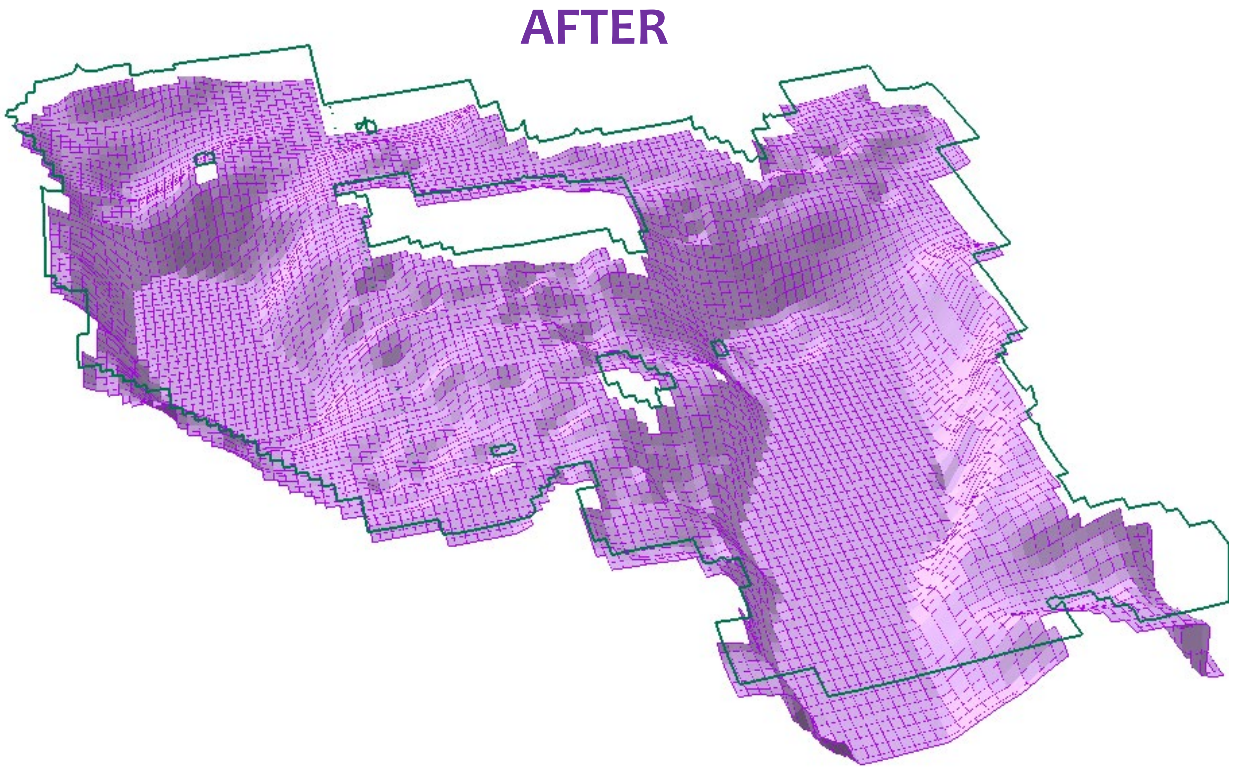


Before and After Layer 3 Bottom. Layer 3 Bottom = Depth to Bedrock except in very deep basin centers, which are still truncated at 3,000 Feet below ground surface (BGS)



Before & After Structural Modifications Model Bottom 3D Representation





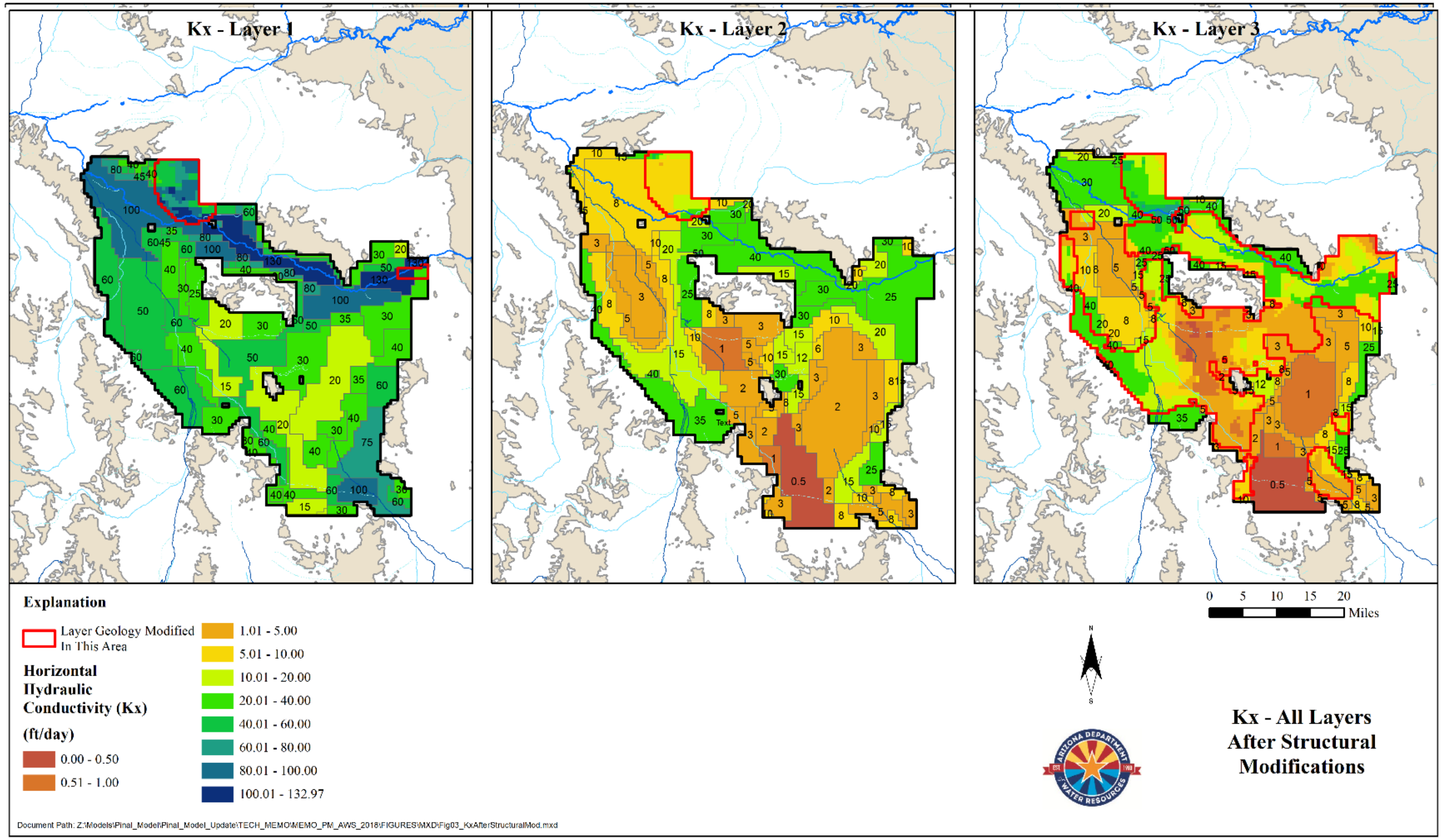
3x vertical exaggeration

Modifications to the Pinal AMA Groundwater Flow Model – Changed Horizonal Hydraulic Conductivity (Kx) to Maintain Transmissivity (T)

(Kx) was modified to maintain the same Transmissivity as the 2014 Pinal model

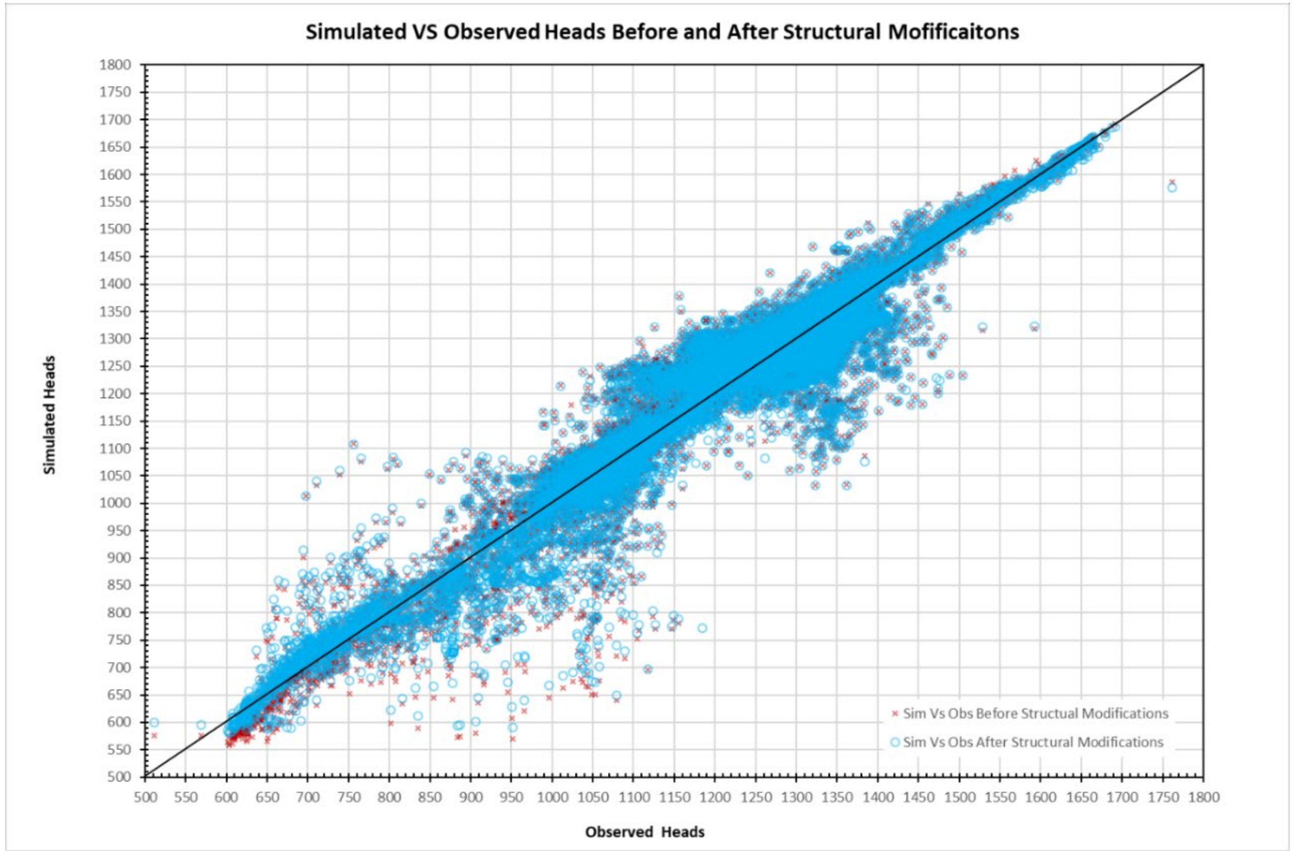
- No other aquifer characteristic (Kz, Ss, Sy) were modified in this version of the Pinal Model
- This version of the model has not been fully re-calibrated using either trial-and-error our automated PEST techniques.

T ≈ K*B



Modifications to the Pinal AMA Groundwater Flow Model – Very Similar Comparative Head Residuals

Using the same set of updated head targets, the locations and magnitudes of model residuals (observed – simulated heads) was very comparable.



* Appendix B of the Tech Memo provides more details on the structural modifications

	Pinal Model Steady-State - 2015 Before Structural Modifications and Original Kx	Pinal Model Steady-State - 2015 After Structural Modifications and Adjusted Kx
Residual Count:	21,057	21,156
Mean:	-1.3	-0.9
Median:	-5.8	-6.2
Count Pos	9,265	9,222
Count Neg	11,792	11,933
Percent Pos	44%	44%
Percent Neg	56%	56%
Count Sim Dry	0	0
StDev:	52.70	53.06
Max:	439.4	430.3
Min:	-353.0	-351.8
Range:	792.4	782.0
Model Error:	4.22%	4.24%
Abs Mean	36.38	36.78
SumSq	58,507,646.91	59,584,339.30
Max ob Elev	1,761.50	1,761.50
Min Ob Elev	511.30	511.30
Ob Elev Range	1,250.20	1,250.20

Model Sensitivity & Calibration of the 2019 Pinal Model

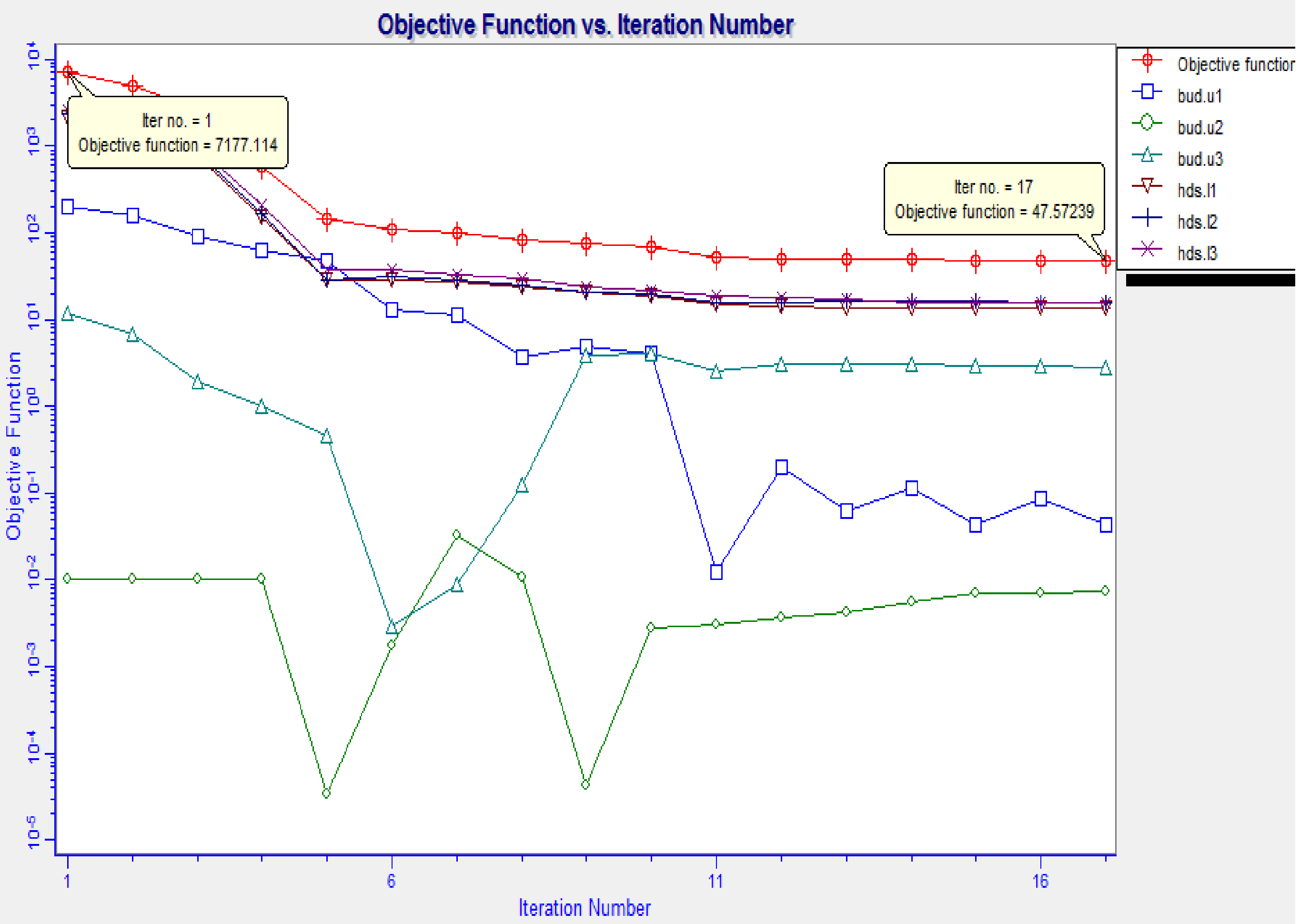
OPTIMISATION RESULTS

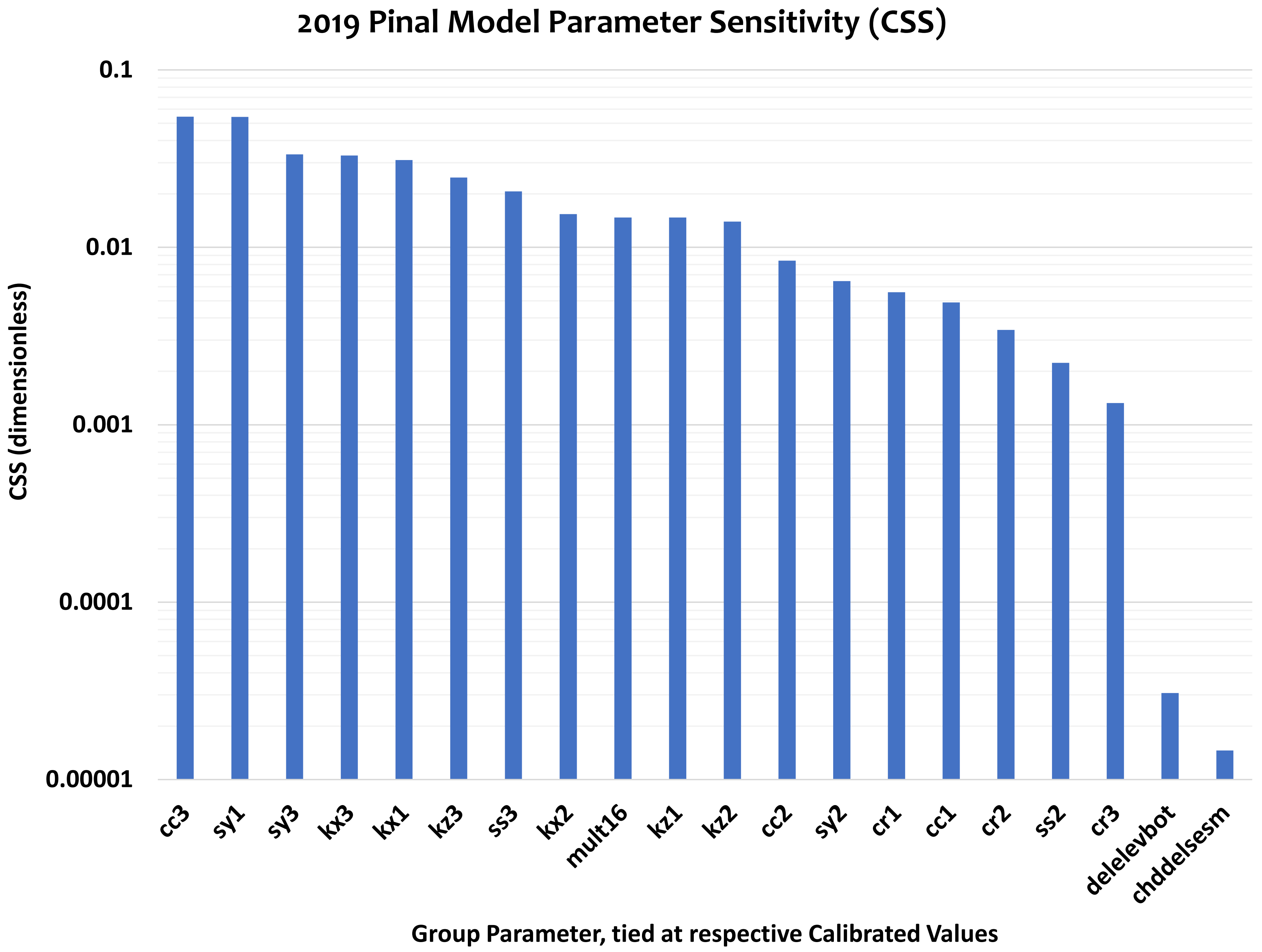
Parameters ----->

Parameter	Estimated value	95% percent confidence limits lower limit	upper limit
cr1	0.100000	7.761510E-02	0.12884
cr2	6.010000E-02	3.289485E-02	0.10980
cr3	3.260000E-02	8.865421E-03	0.11987
cc1	0.400000	0.283628	0.56411
cc2	0.327000	0.289759	0.36902
cc3	0.389100	0.363912	0.41603
kx1	1.09111	1.03790	1.1470
kx2	2.00000	1.85146	2.1604
kx3	0.920813	0.898972	0.94318
kz1	2.00000	1.70723	2.3429
kz2	1.55451	1.40994	1.7138
kz3	0.929674	0.870961	0.99234
ss2	0.500000	0.371113	0.67365
ss3	1.10530	0.924243	1.3218
sy1	0.888855	0.864006	0.91441
sy2	0.874723	0.773229	0.98953
sy3	1.18305	1.13363	1.2346
delelevbot	0.474912	-6.81553	7.7653
chddelsesm	0.352029	-18.8182	19.522
mult16	1.50470	1.44345	1.5659

Note: confidence limits provide only an indication of parame
They rely on a linearity assumption which may not ext
parameter space as the confidence limits themselves -

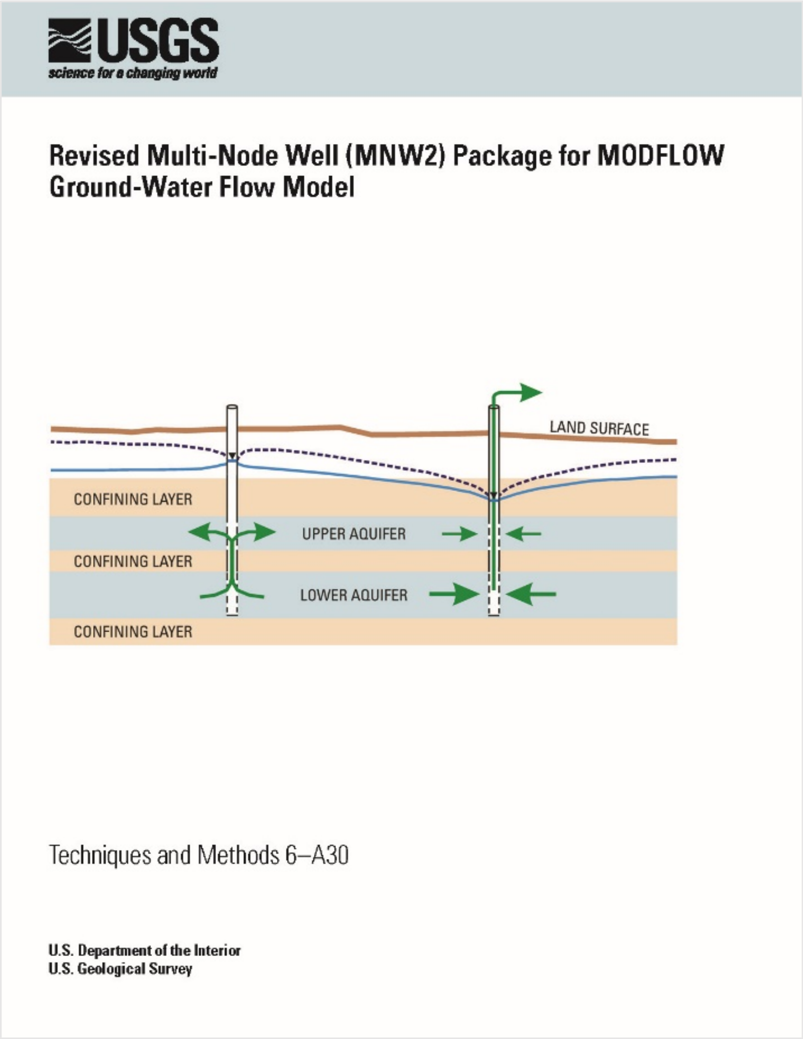
See file pm_302a_p11__run26.sen for parameter sensitivities.




2019 Pinal Model Parameter Sensitivity (CSS)
CSS (dimensionless)
0.1
0.01
0.001
0.0001
0.00001
cc3
sy1
sy3
kx3
kx1
kz3
ss3
kx2
mult16
kz1
kz2
cc2
sy2
cr1
cc1
cr2
ss2
cr3
delelevbot
chddelsesm
Group Parameter, tied at respective Calibrated Values

Vertical Distribution of Pumping and the Use of the Multi-Node Well (MNW) Package

- **Historic Period (1923 – 2015) Used Traditional Modflow Well Package (WEL)**
- **Projection Period (2016 – 2115) Used the new Multi-Node Well Package (MNW)**
  - Where available, construction information was used for existing wells
  - Where construction information was unavailable, each location was assigned between 1 and 3 vertical nodes.


USGS
science for a changing world

Revised Multi-Node Well (MNW2) Package for MODFLOW Ground-Water Flow Model

Techniques and Methods 6–A30

U.S. Department of the Interior
U.S. Geological Survey

Simulated Unmet Demand

Simulation of Unmet Demands Occurs When:

- Model layers become dewatered
- The simulated water level falls below the bottom of the well's perforated depth
- The decrease in the saturated thickness and corresponding aquifer transmissivity, otherwise known as the formation of a seepage face.

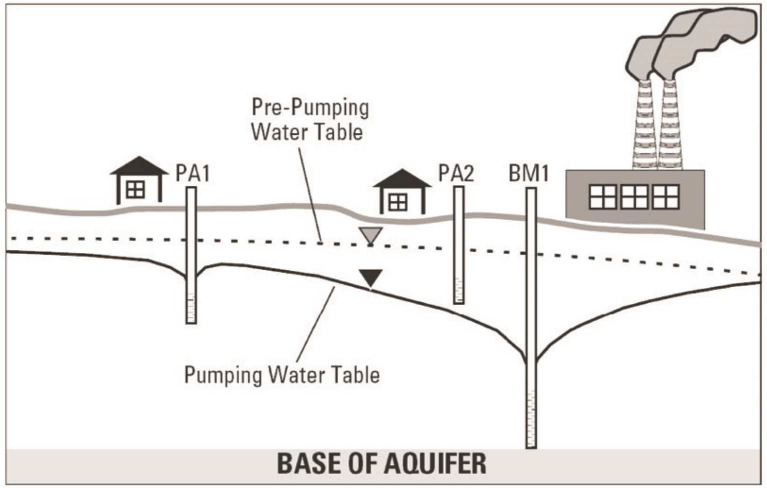
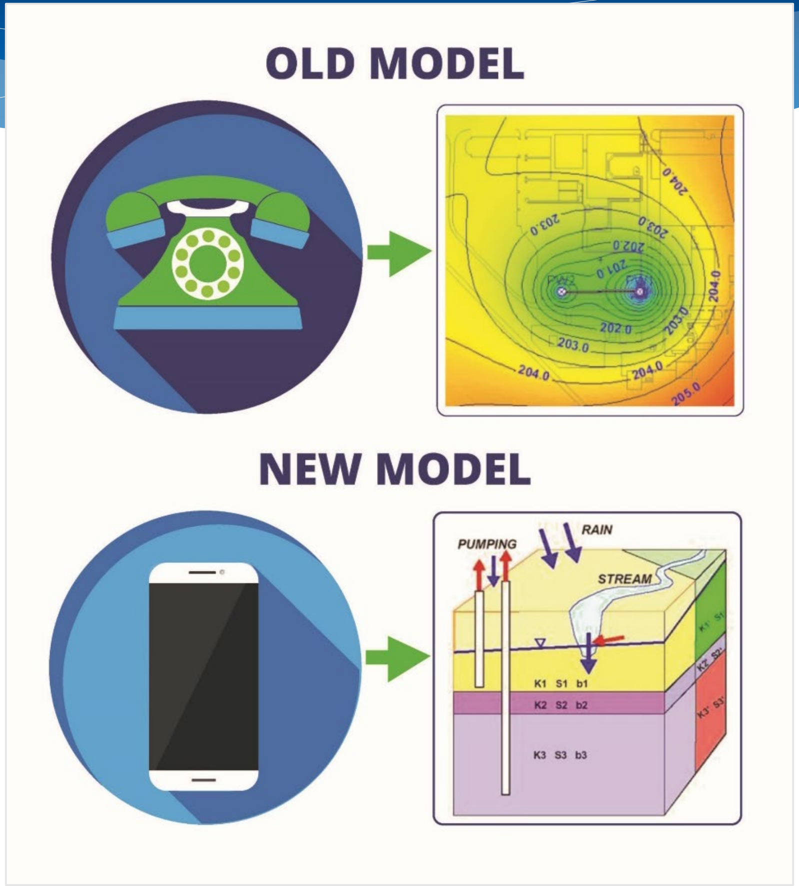


Figure 23. Hypothetical cross-section illustrating limitations on well discharge rates owing to aquifer characteristics, well construction, and influence of other wells (from Halford and Hanson, 2002).

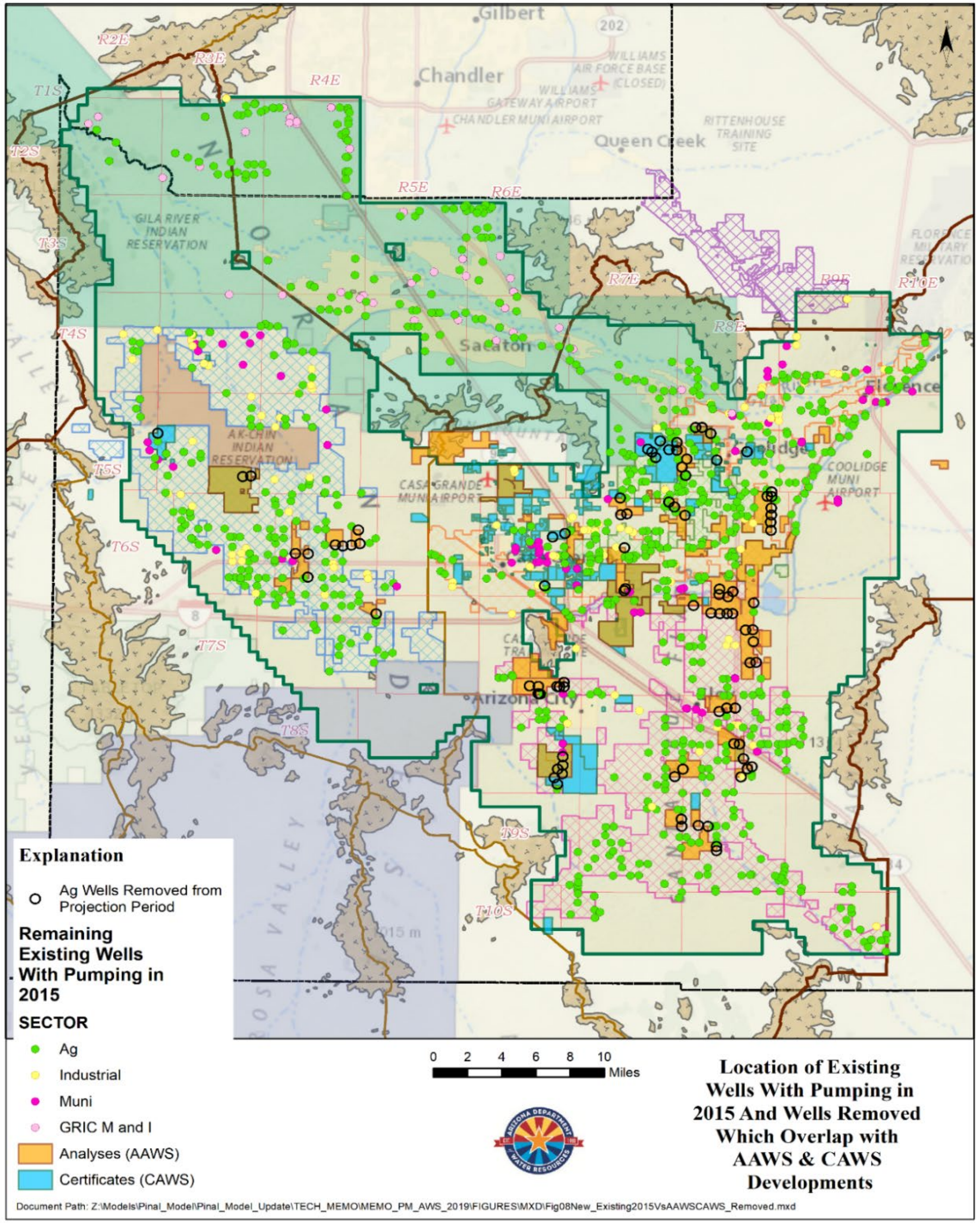
100-Year Assured Water Supply Results in the Pinal AMA

History of Model Use for Assured Water Supply (AWS) Applications in the Pinal AMA

- **Prior to 2013 AWS applicants submitted analytical and local numeric models.**
  - Earlier applications did not always consider regional conditions and demands
  - These models used simplified assumptions
- **2014 – ADWR completed regional numerical groundwater model**
  - Developed to be used for many purposes including assured water supply
- **2019 – ADWR completed updated model and applied 100-Year Assured Water Supply Projection**
  - Projection is “deterministic” model run (one scenario)
  - One set of assumptions/inputs
  - Produces one set of results



- **Best tool available for assured water supply purposes**
- **Enhances consumer protection**



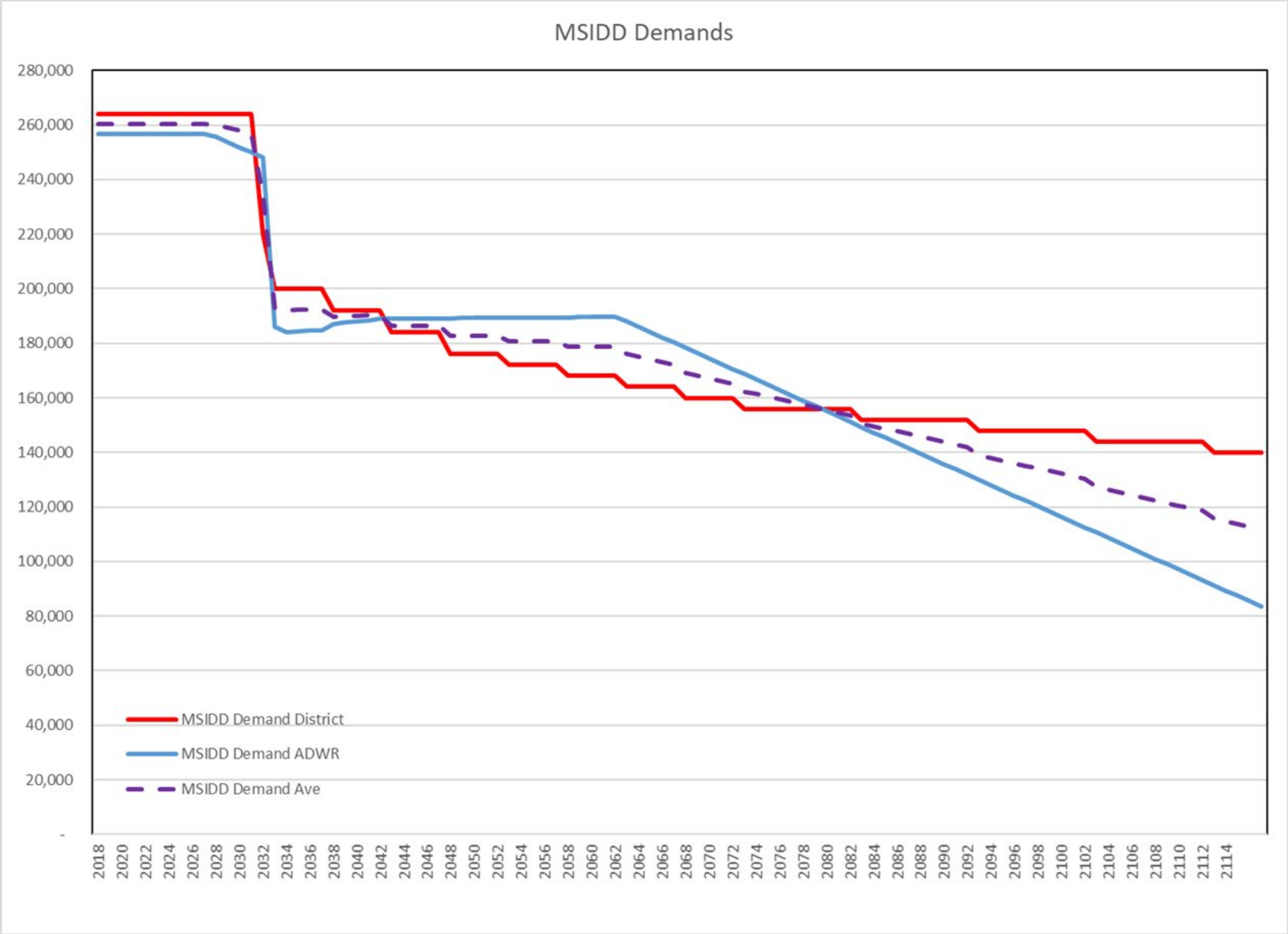
Existing Groundwater Use Assumptions

- Existing Municipal and Industrial groundwater withdrawals are based on reported 2015 pumping data and carried forward through 100-year projection period.
- Existing Municipal withdrawals include the built-out portions of developments with issued Certificates of Assured Water Supply.
- Existing Agricultural groundwater withdrawals are based on reported 2015 pumping data
- Within the Analysis of Assured Water Supply (AAWS) and Certificate of Assured Water Supply (CAWS) development footprints, agricultural wells that were active in 2015 are not assigned any further pumping during the 2016 – 2115 projection period.

Agricultural Assumptions

- Agricultural lands with certificates and analyses of assured water supply overlays/footprints are assumed to urbanize at the beginning of the projection period (2016).
- ADWR discontinued agricultural pumping and associated incidental agricultural recharge for these agricultural lands (assured water supply demands were applied to these lands).
- ADWR assumed full CAP Ag Pool deliveries through 2030

Maricopa Stanfield Irrigation & Drainage District



100-year ADWR Acreage Estimates

- Reduction from 70,000 acres to 22,000 acres

100-year MSIDD Acreage Estimates

- Reduction from 60,000 acres to 35,000 acres

100-year ADWR Water Demand Estimates

- Reduction from 257,000 AF/Yr to 84,000 AF/Yr

100-year MSIDD Water Demand Estimates

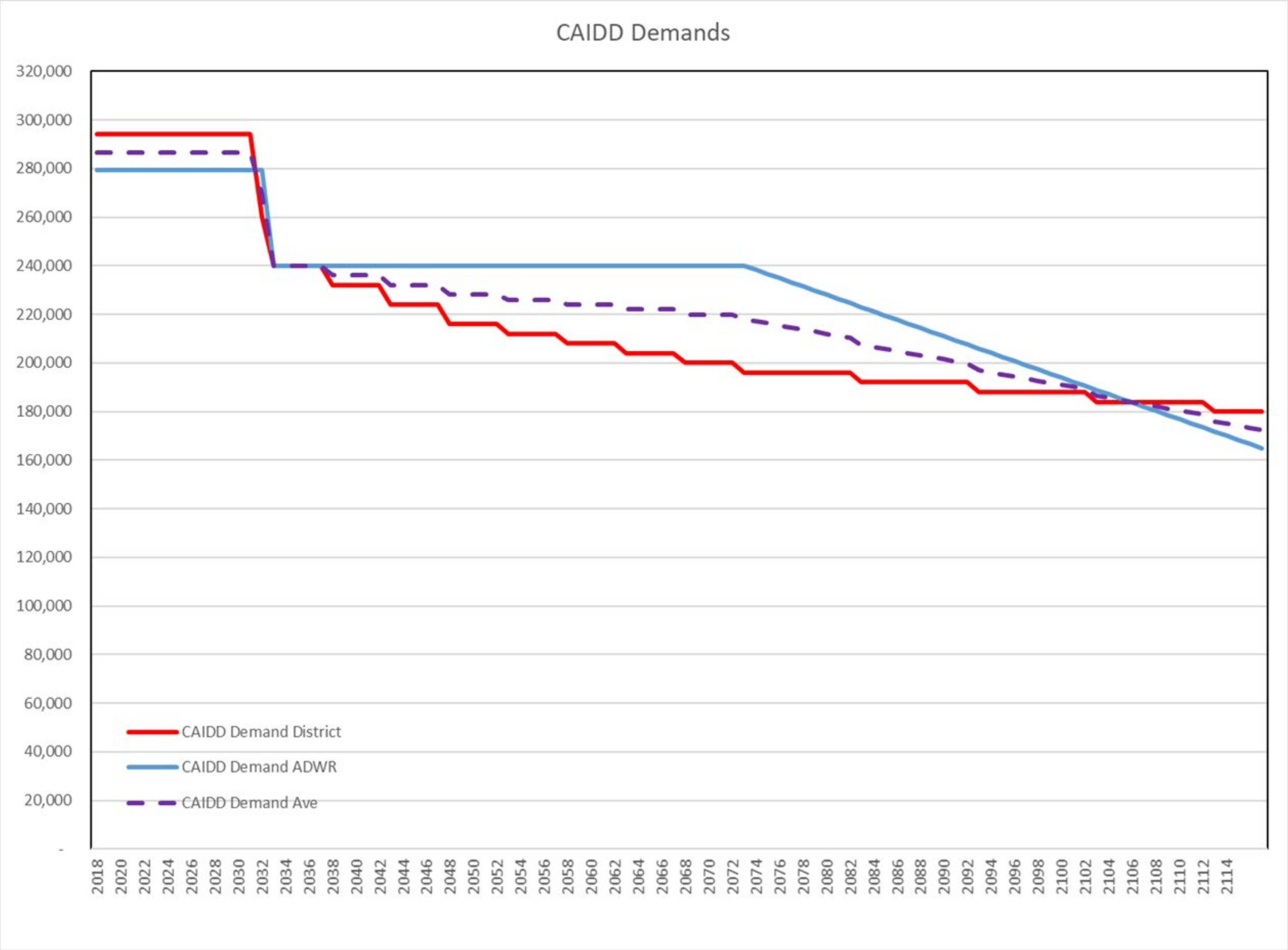
- Reduction from 264,000 AF/Yr to 140,000 AF/Yr

ADWR and MSIDD water demand projections were averaged and used in the model run

100-year Average Water Demand Estimates

- Reduction from 260,000 AF/Yr to 112,000 AF/Yr

Central Arizona Irrigation & Drainage District



100-year ADWR Acreage Estimates

- Reduction from 70,000 acres to 41,000 acres

100-year CAIDD Acreage Estimates

- Reduction from 70,000 acres to 45,000 acres

100-year ADWR Water Demand Estimates

- Reduction from 279,000 AF/Yr to 165,000 AF/Yr

100-year CAIDD Water Demand Estimates

- Reduction from 294,000 AF/Yr to 180,000 AF/Yr

ADWR and CAIDD water demand projections were averaged and used in the model run

100-year Average Water Demand Estimates

- Reduction from 287,000 AF/Yr to 172,000 AF/Yr

Gila River Indian Community

- Annual agricultural demands assumed an expansion of agricultural areas from 94,696 acres to 146,411 acres, with 129,859 agricultural acres within the Pinal model area.
- Approximately 89% of Community agricultural lands located within Pinal Model area.
- Total estimated on reservation agricultural demand within the Pinal model area ranged from 266,000 AF/Yr to 476,000 AF/Yr
- The model simulates full use of CAP water on reservation beginning in 2029

Other Agricultural Users

Hohokam Irrigation & Drainage District

- 28,825 acres total district acres
- 13,686 acres within district with CAWS and AAWS development overlays
- 15,139 acres remaining irrigated acres
- 57,000 AF/Yr total estimated demand for remaining irrigated acres
- Total demand held constant through 100-year projection period

San Carlos Irrigation & Drainage District

- 49,041 acres total district acres
- 9,237 acres within district with CAWS and AAWS development overlays
- 39,804 acres remaining irrigated acres
- 86,100 AF/Yr total estimated demand for remaining irrigated acres
- Total demand held constant through 100-year projection period

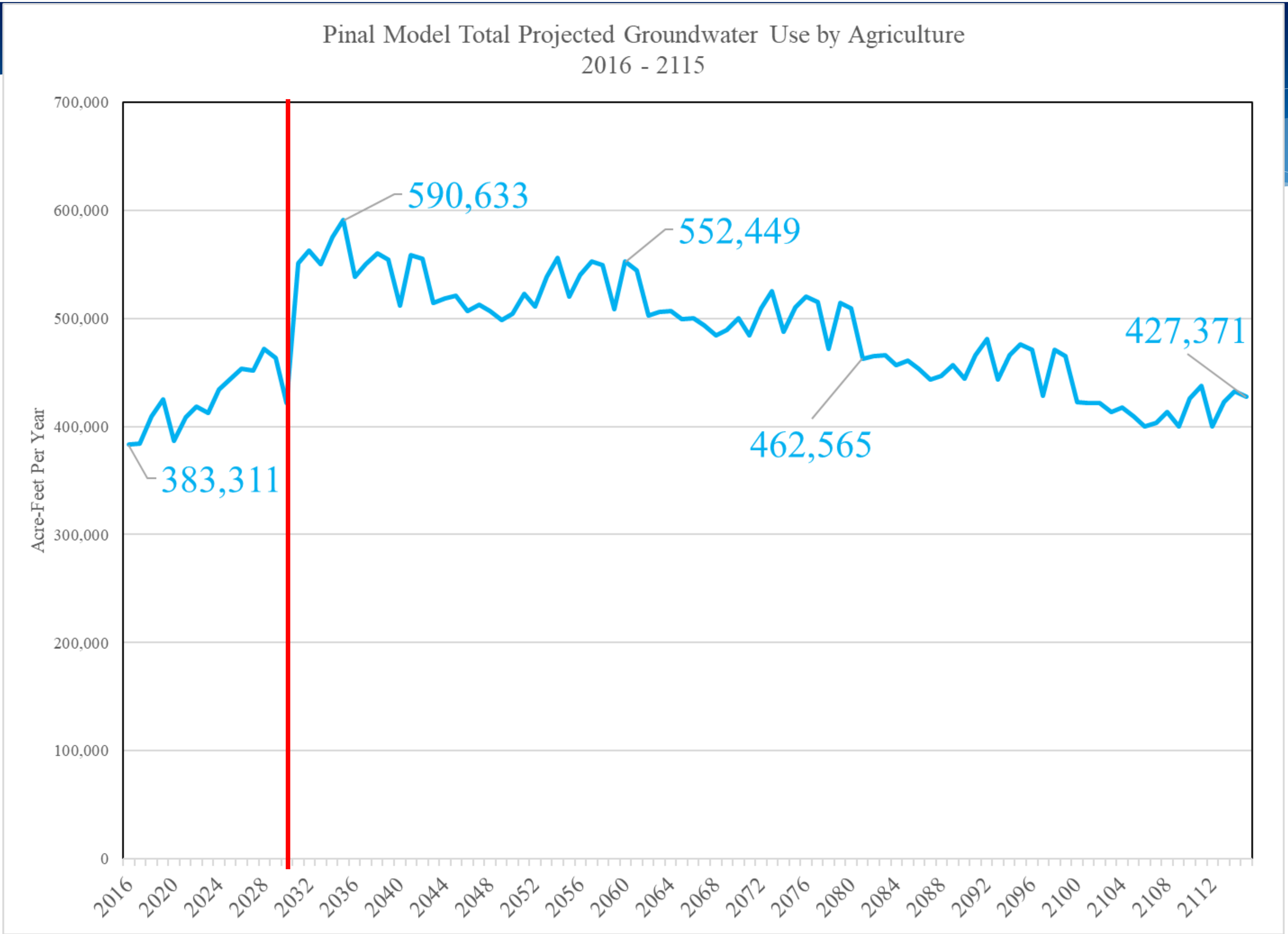
Ak-Chin Indian Community

- 72,000 AF/Yr total estimated demand using 100% CAP water

Non-District Irrigation Grandfathered Rights (IGFRs)

- 27,000 AF/Yr total estimated demand based on 2015 reported use for IGFRs without CAWS & AAWS development overlays
- Total demand held constant through 100-year projection period

Southern Arizona Agricultural Field in Pinal County


Pinal Model Total Projected Groundwater Use by Agriculture
2016 - 2115
Acre-Feet Per Year
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
383,311
590,633
552,449
462,565
427,371
2016
2020
2024
2028
2032
2036
2040
2044
2048
2052
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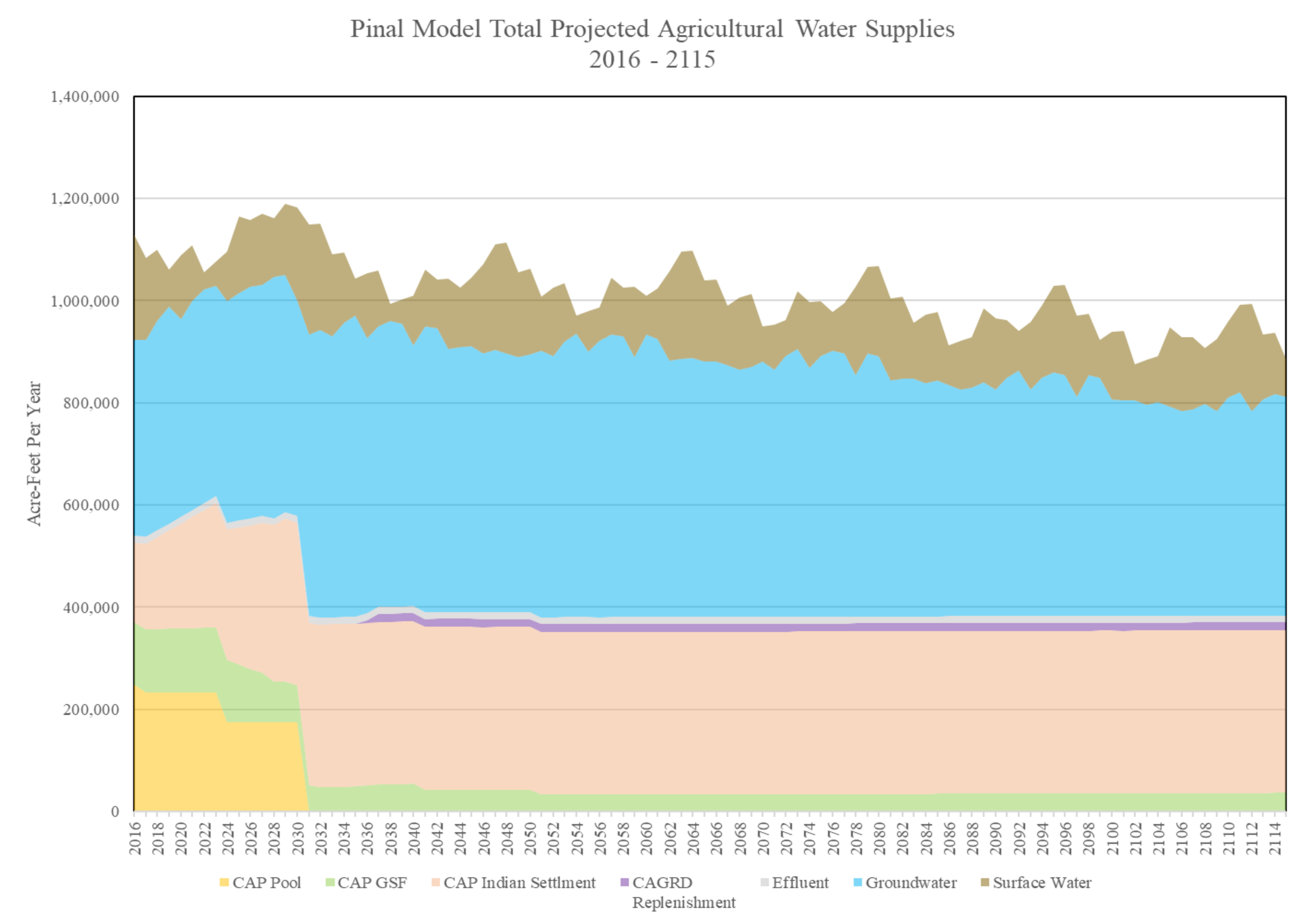
2100
2104
2108
2112


Pinal Model Total Projected Agricultural Water Supplies
2016 - 2115
Acre-Feet Per Year
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
2016
2018
2020
2022
2024
2026
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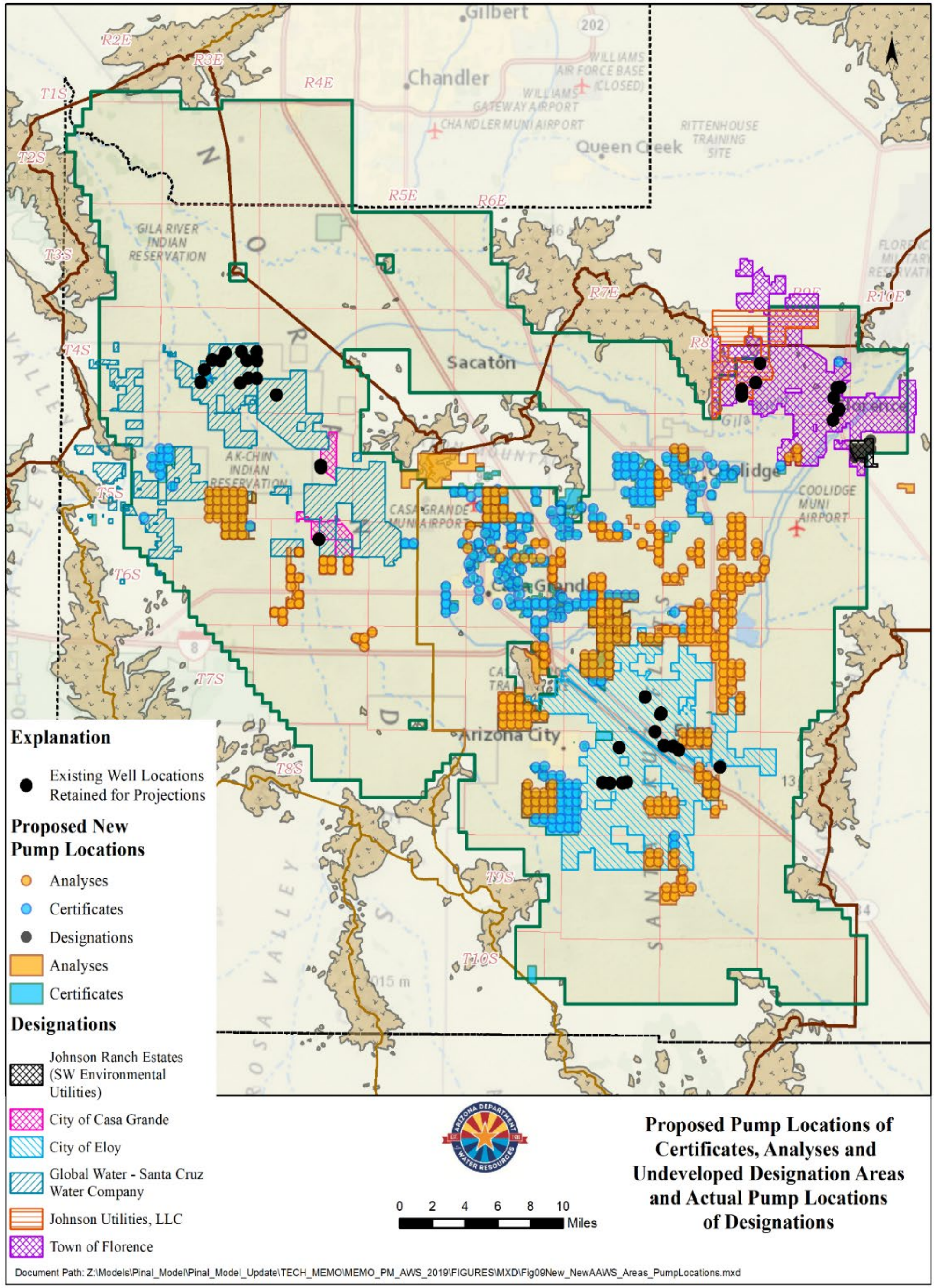
2104
2106
2108
2110
2112
2114
CAP Pool
CAP GSF
CAP Indian Settlment
CAGRD Replenishment
Effluent
Groundwater
Surface Water

Proposed New Groundwater Use



- Remaining Issued Volumes for Issued Analyses of Assured Water Supply
- Unbuilt Portions of Certificates of Assured Water Supply
- For the issued, but unserved AAWS and CAWS demands, new wells were created and placed within each AWS determination's development footprint.
- Full Use of Designations of Assured Water Supply. The fully issued volume was simulated to be pumped from their existing well network.
  - Eloy demand reduced significantly
  - Global Water - Santa Cruz Water Co. correction
- Wells in the Sacaton Mountain area that were outside of the model area were moved to active model cells.

Assured Water Supply Issued Determinations in Pinal AMA Model Area

	Analyses	Certificates	Designations	TOTALS
Issued Determinations (count)	40	209	6	255
Issued Demand (AF/YR)	126,973	55,763	48,865	231,601
Built-out and Served Demand (AF/YR)	NA	5,991	NA	5,991
Certificated Demand (AF/YR)	10,101	NA	NA	10,101
Total Demand in Model (AF/YR)	116,872	48,754	48,865	214,491
100-Year Cumulative Demand (AF)	11,687,181	4,875,410	4,886,490	21,449,081

Long-Term Storage Credits Removal

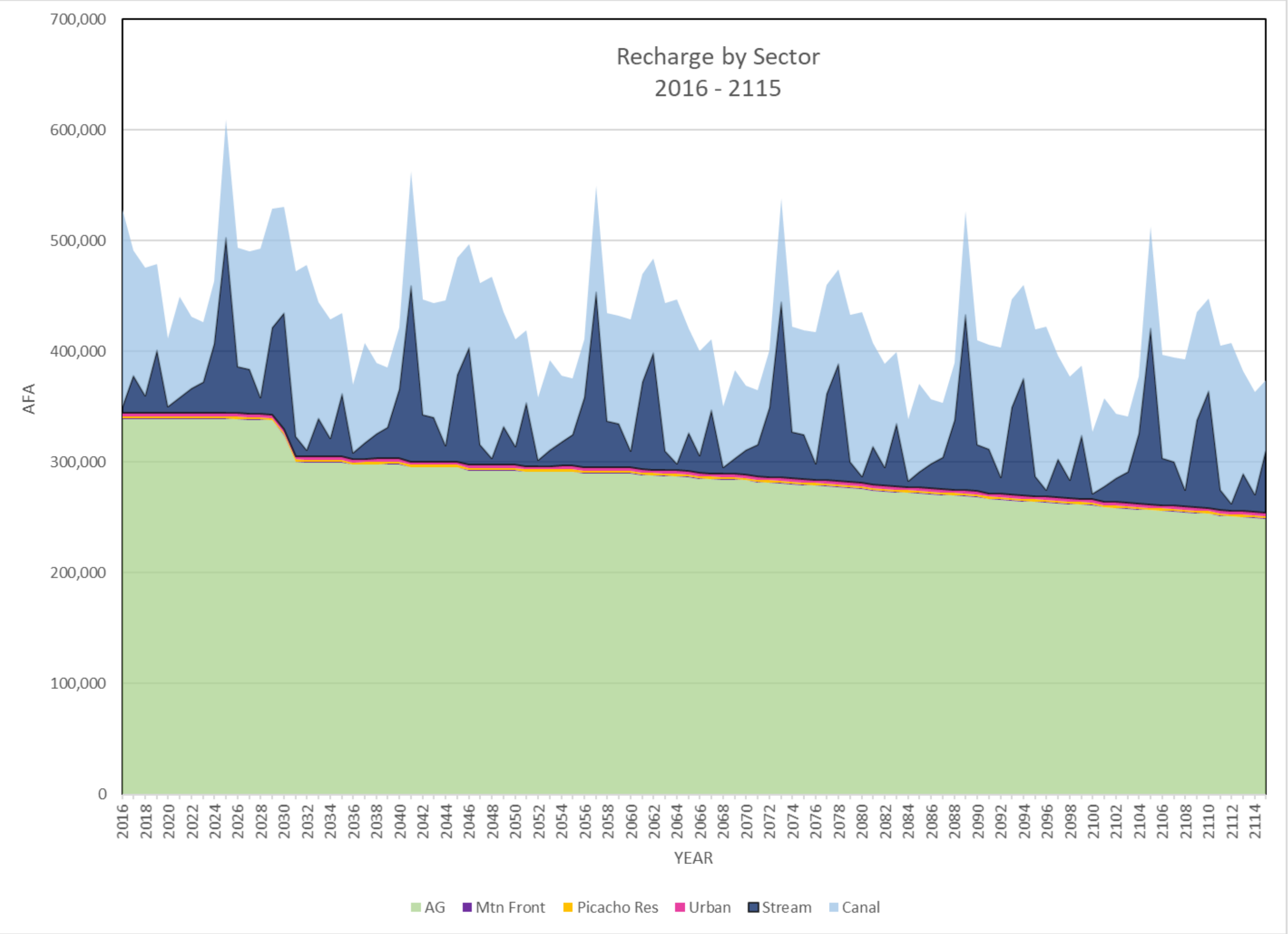
- Long-Term Storage Credits (LTSCs) stored by others may not be relied on by AWS applicants and therefore must removed from model.
- 14,556 AF of LTSCs accrued at Underground Savings Facilities (USFs) through 2015.
- 1,155,437 AF of LTSCs (excluding Central Arizona Groundwater Replenishment District (CAGRD) LTSCs) accrued Groundwater Savings Facilities (GSFs) through 2015.
- Non-CAGRD LTSCs accrued through 2015 were removed from the model at a uniform annual rate over the 100-year projection period.
- LTSC accrued GSFs in the projection period (2016-2115) are removed at a rate of 95% in the same year as they were accrued with a residual 5% remaining in the aquifer ("cut to the aquifer').
- 4,386,291 AF total LTSCs accrued at GSFs and removed during the projection period.
- 230,857 AF of residual LTSCs "cut to aquifer"
- Future LTSC accrual at USFs was not simulated in the model during the 100-year projection period.

Central Arizona Groundwater Replenishment District

- Total Pinal AMA Replenishment obligations are limited to a maximum annual rate 15,500 AFA based on the CAGRD 2015 Plan of Operation.
- 320,279 AF of LTSCs accrued by the CAGRD through 2015.
- Accrued CAGRD LTSCs were extinguished at a rate of 15,500 AF/Yr for replenishment purposes in early years to meet replenishment obligations. Covers 20.66 year of replenishment obligations.
- Remaining CAGRD replenishment obligations during the projection period were met through storage of CAP water in GSFs located near the AWS developments where the replenishment obligations were incurred.

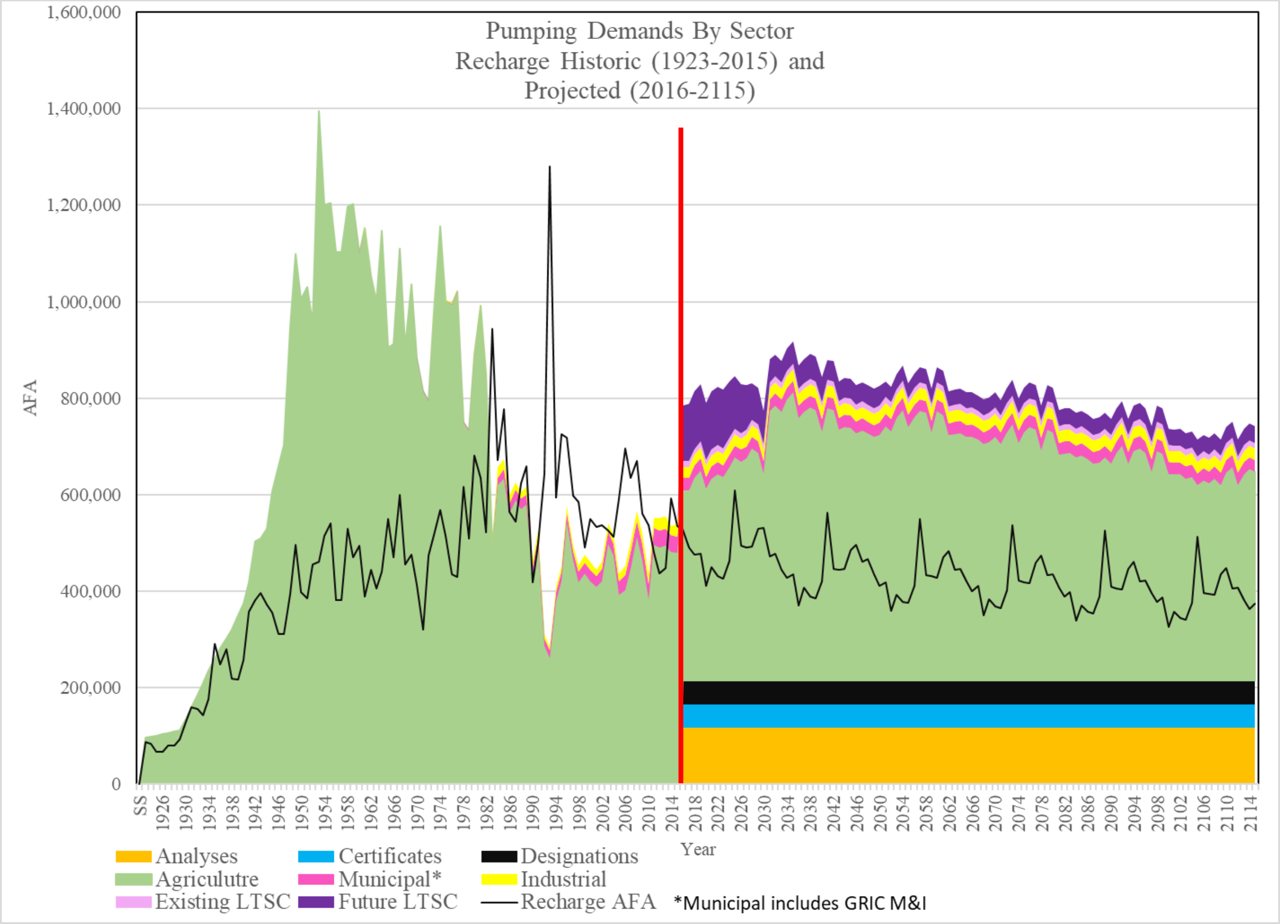
Recharge Projections

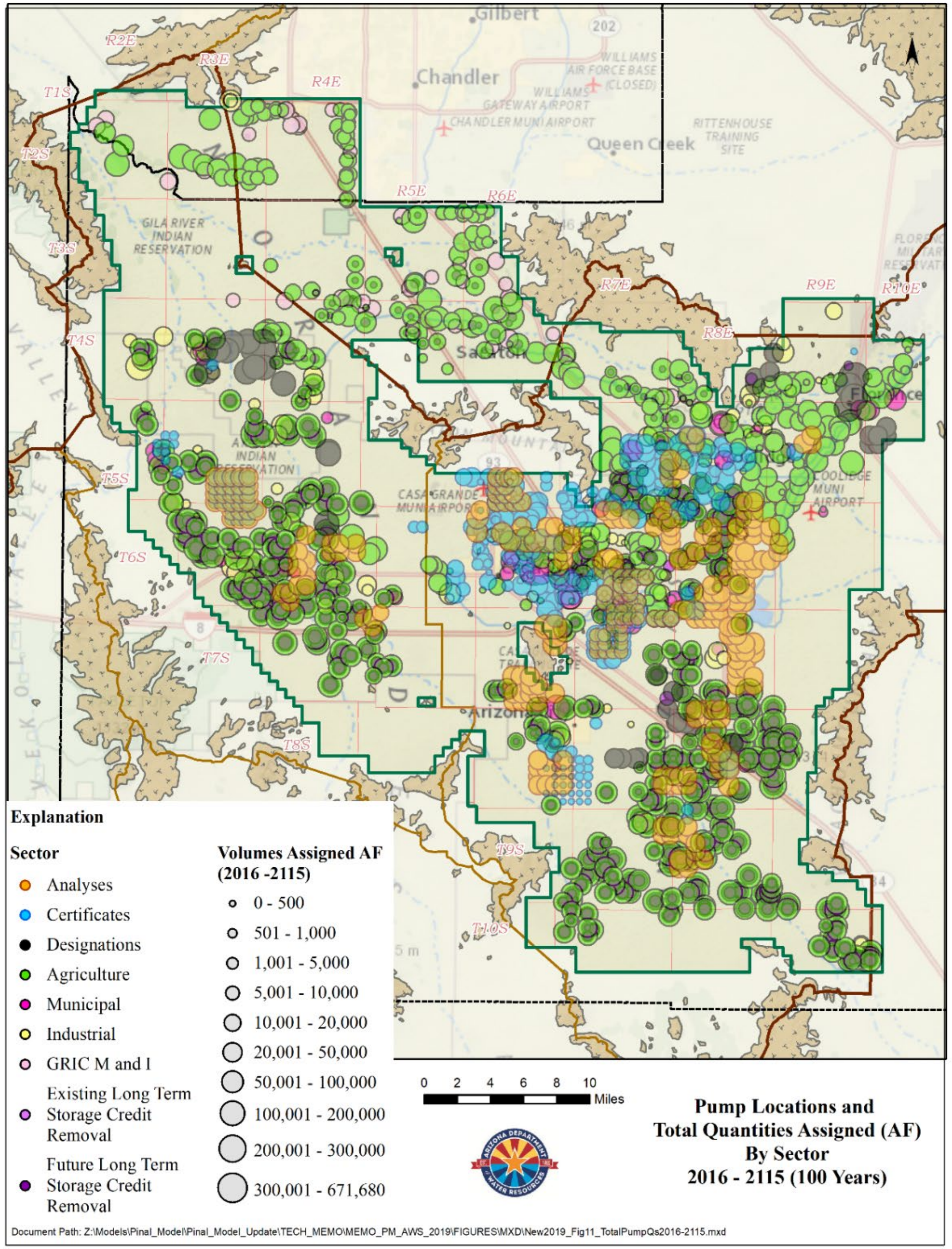
- Future agricultural incidental recharge will be applied evenly on remaining active irrigable acres at a 34% rate based on dominant use of flood irrigation in Pinal.
- Agricultural incidental recharge is not lagged during the projection period
- Stream and canal recharge follow the previous pattern observed from 1995 – 2010 and is repeated every 16 years through the projection period.
- All other types of recharge (Urban, Mountain Front, Picacho Reservoir) remain held constant from 2014 model.



100 Year Groundwater Demands By Sector

- Agriculture simulated to remain dominant groundwater user, with significant demands from issued and not-yet-built AWS users.
- Pumping Simulated to Outpace Natural and Incidental Recharge





2019 Pinal AMA Model Demands

Sectors	Total Demand (AF)	Total Demand (%)
Analysis (AAWS)	11,687,181	14%
Certificates (CAWS)	4,875,410	6%
Designations (DAWS)	4,886,490	6%
AWS Subtotal	***21,449,081***	**27%**

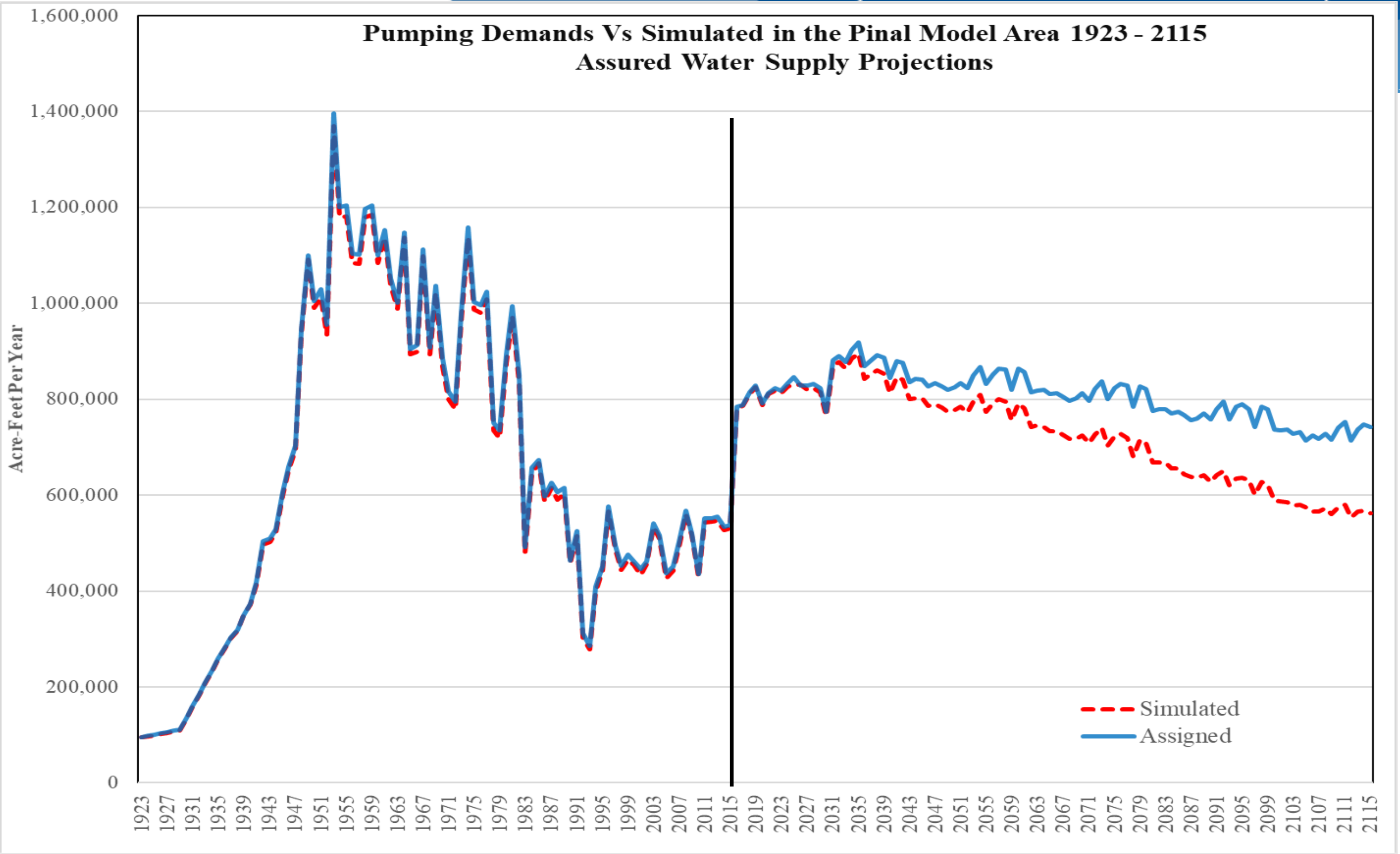
Sectors	Total Demand (AF)	Total Demand (%)
Agriculture	48,573,365	60%
Municipal	2,005,524	2%
GRIC M&I	500,342	1%
Industrial	2,329,255	3%
Existing Uses Subtotal	**53,408,486**	**66%**
Existing LTSC	1,169,993	1%
Future LTSC	4,620,964	6%
LTSC Subtotal	***5,790,958***	***7%***

Total Demand (AF)	Total Demand (%)
80,648,525	**100%**

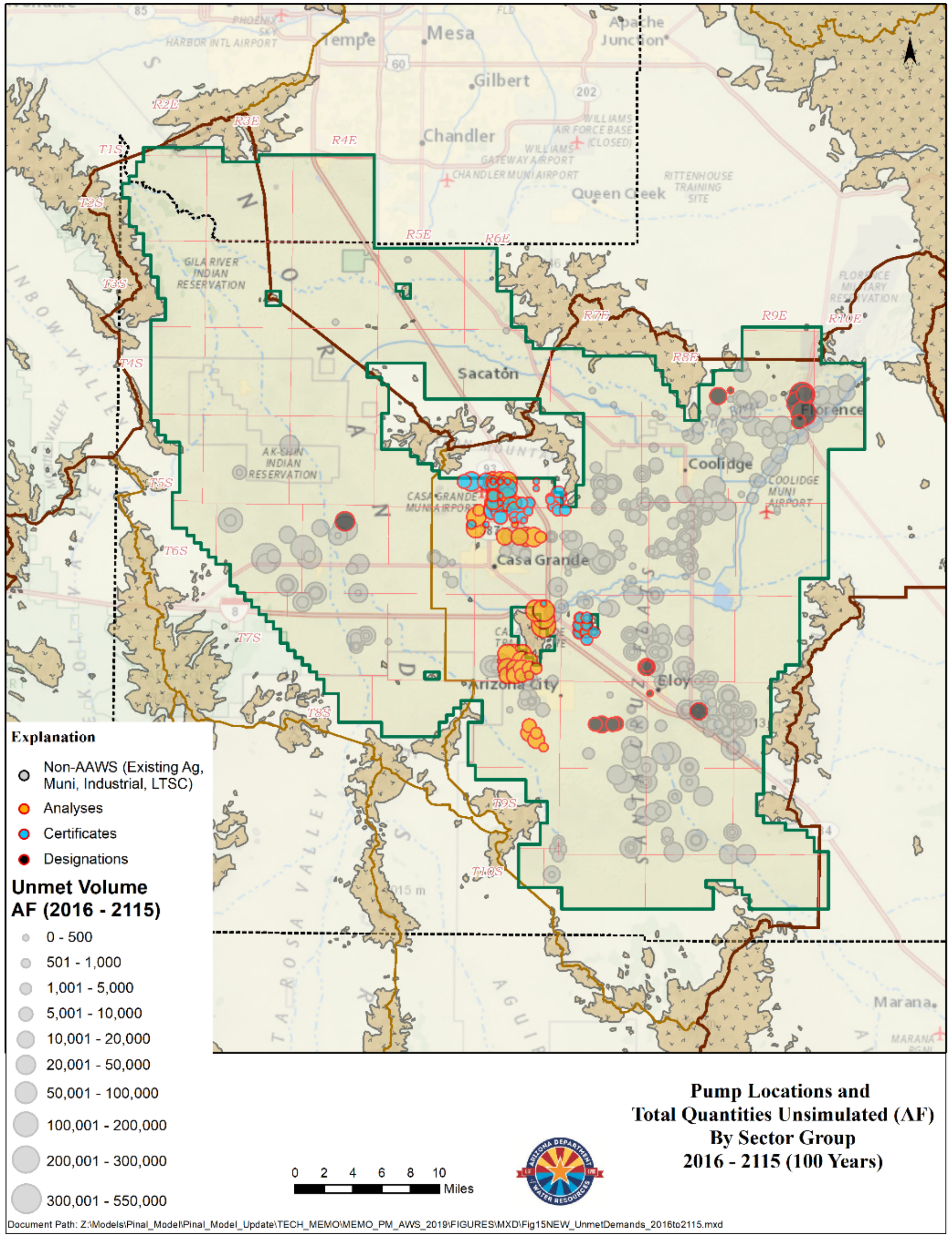
2019 Pinal Model Results

2019 Pinal Model 100-Year Cumulative Projections	100-Year Projection 2016 - 2115
Total Demand (AF)	**80,648,525**
Simulated Demand (AF)	72,560,695
Unmet Demand (AF) (Total - Simulated)	8,087,830
AWS Unmet Demand (AF)	1,969,950
Agricultural Unmet Demand (AF)	5,059,056
Existing M&I Uses Unmet Demand (AF)	782,112
LTSC Removal Unmet Demand (AF)	276,712

Model Results



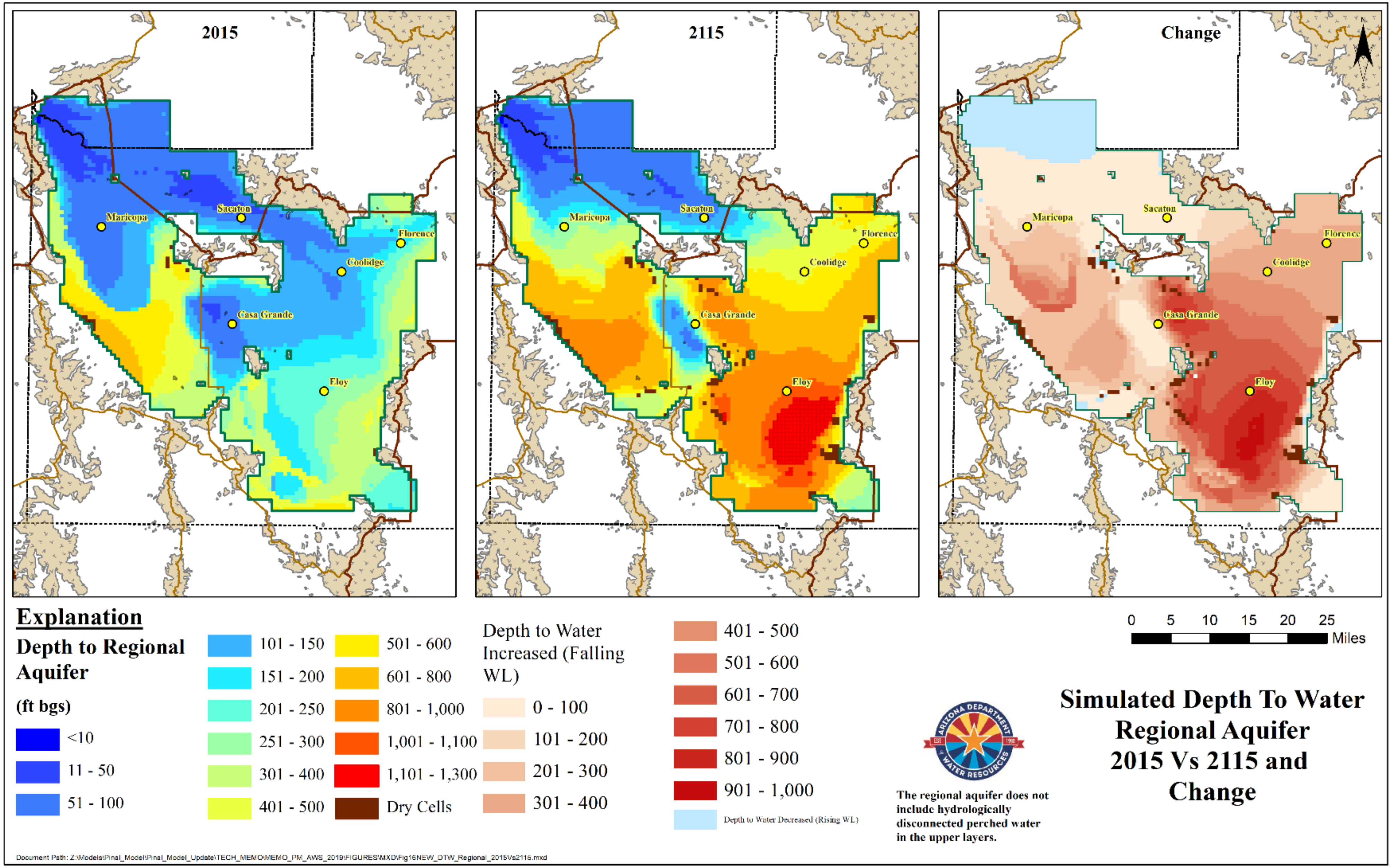
Locations of Unmet Demands



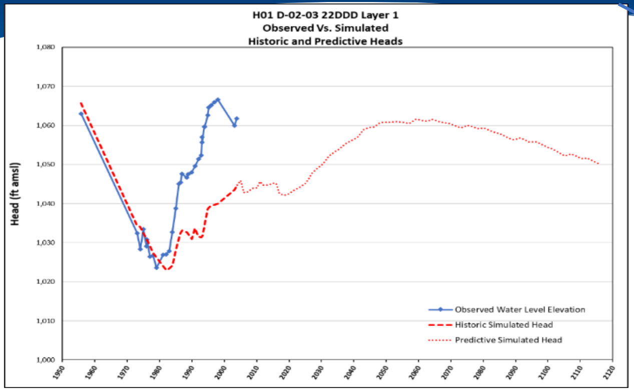
Simulation of Unmet Demands Occurs When:

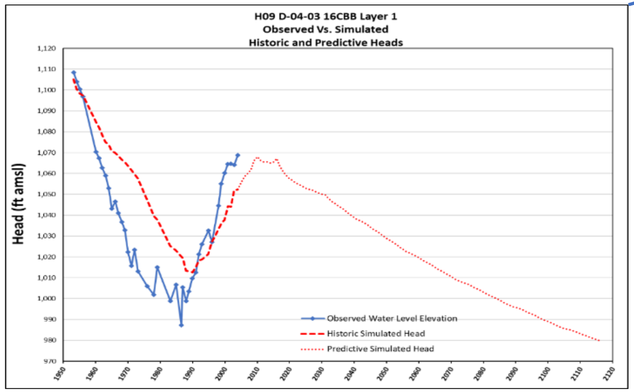
1. Model layers become dewatered
2. The simulated water level falls below the bottom of the well's perforated depth
3. There is a decrease in the saturated thickness and corresponding aquifer transmissivity

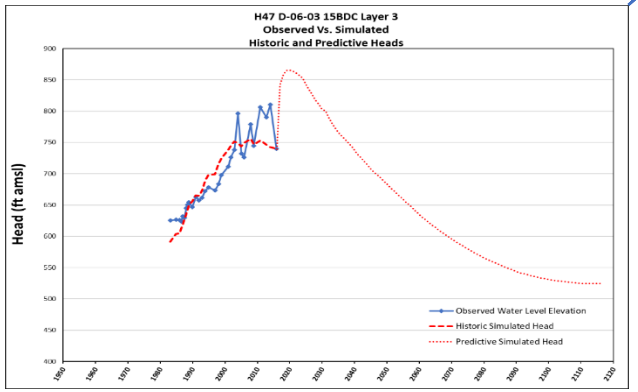
Simulated Depth To Water Before & After 100 Years of Pumping

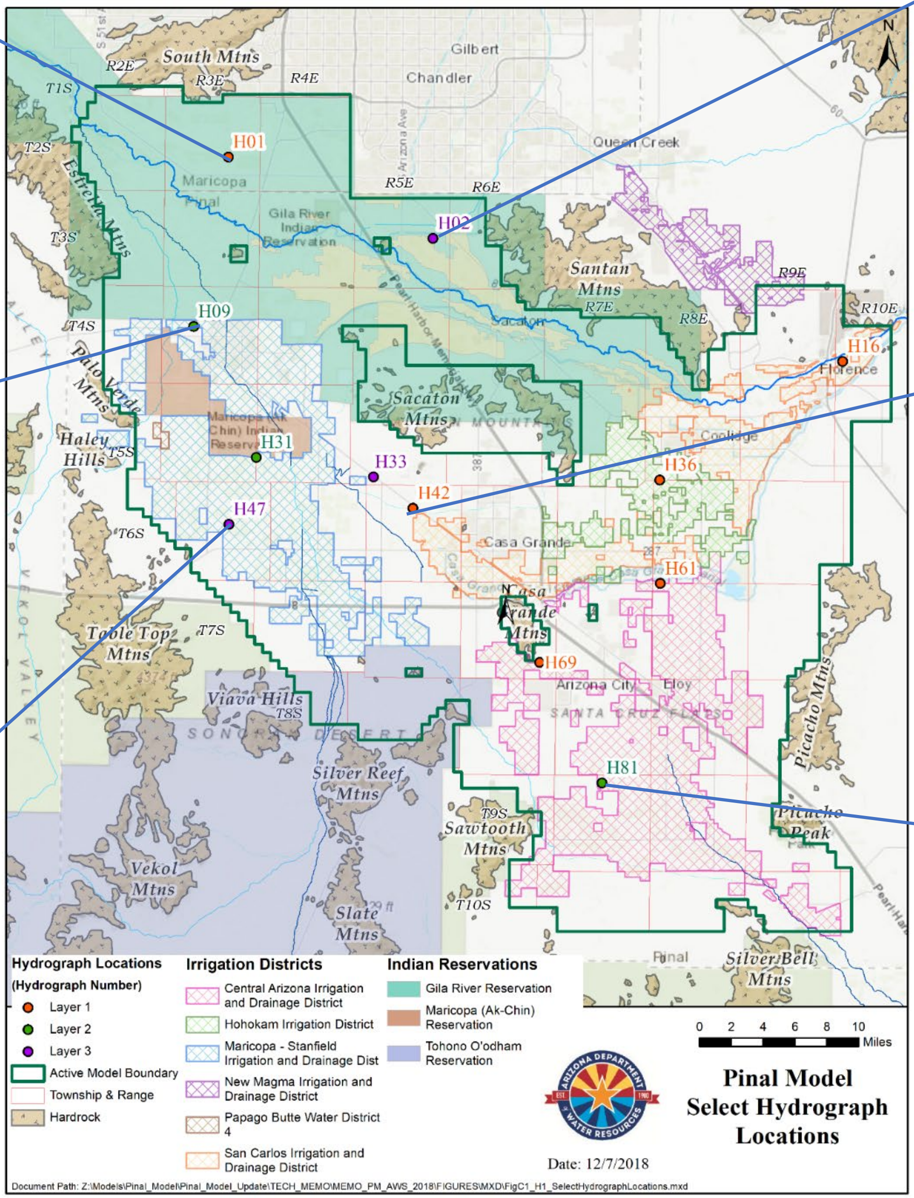


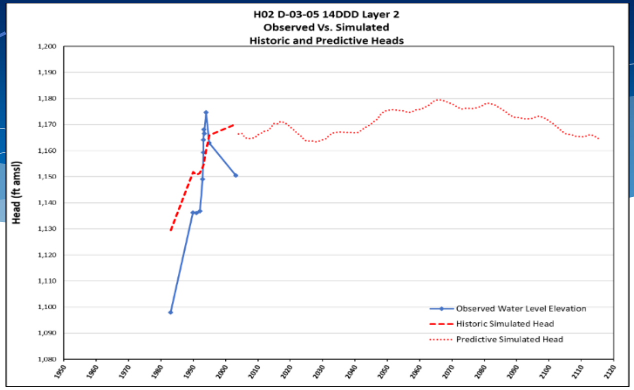
Projected Hydrographs

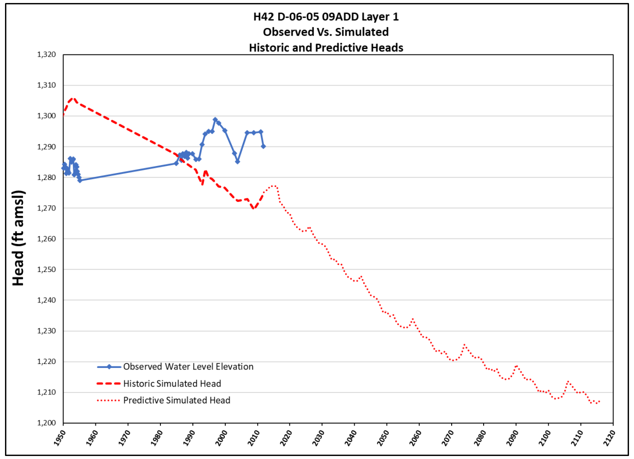


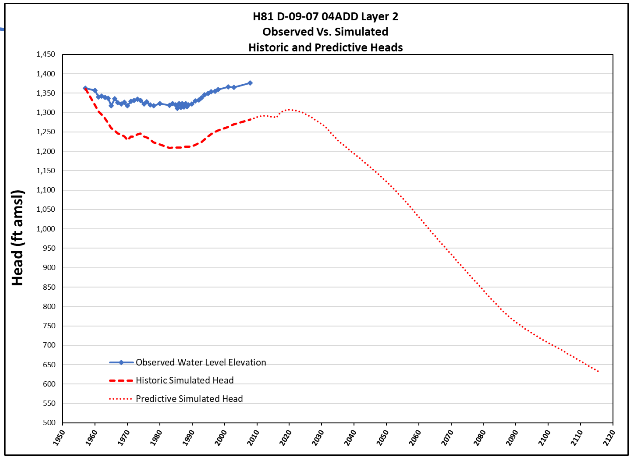






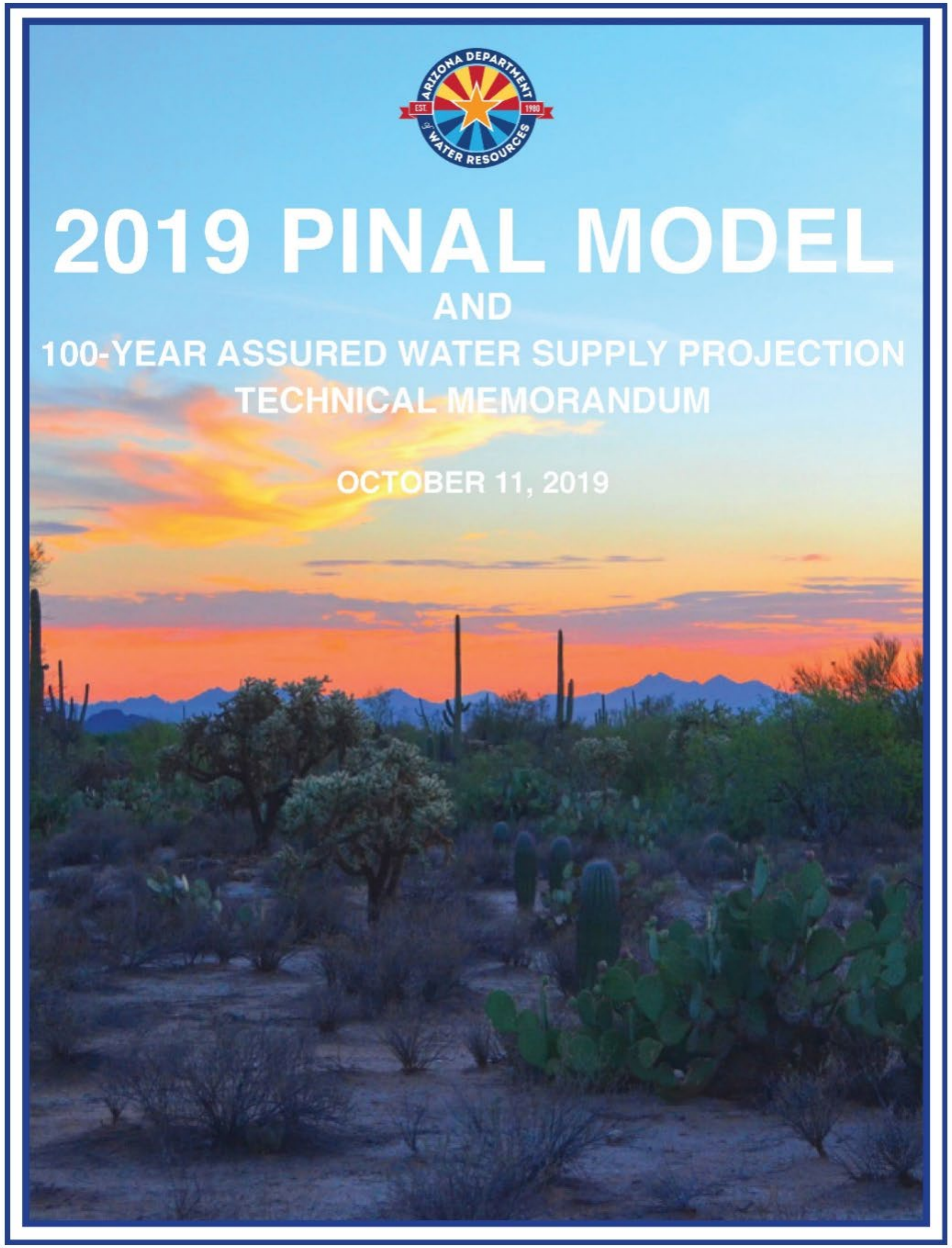






Simulated Loss of Water From Storage

Budget Term	Cumulative Acre Feet			
	Steady State (1 Day)	1923 - 2015 (93 Years)	2016 - 2115 (100 Years)	Total
Net Loss in Aquifer Storage (Out - In)				
Interbed (From Subsidence)	**0**	**-2,215,546**	**-4,307,052**	**-6,522,597**
Non-Interbed	**0**	**-15,146,838**	**-23,210,709**	**-38,357,547**
Total	**0**	**-17,362,384**	**-27,517,760**	**-44,880,144**



ADWR Files Posted To Website

Technical Memorandum:
http://infoshare.azwater.gov/docushare/dsweb/View/Collection-19686

Model Files & GIS Data:
https://new.azwater.gov/hydrology/groundwater-modeling/pinal-regional-model

Contact ADWR, Hydrology with Questions
602-771-8680

Next Steps

Next Steps

- The State's Guiding Principles for Future Solutions
- 2019 Pinal Stakeholder Group
- Pending Applicant Process
- Groundwater Redistribution Substantive Policy Statement

The State's Guiding Principles for Future Solutions

1. We must continue the State's commitment to upholding the consumer protection and water sustainability objectives of the Assured Water Supply Program.
2. The stakeholder process should be community driven. The State's role will be to provide assistance and comment on proposals.

2019 Pinal Stakeholder Group

- A Pinal Active Management Area Stakeholder Group has been proposed by Representative Cook, chairman of the Arizona House Ad Hoc Committee on Groundwater Supply in Pinal County, to address the Assured Water Supply groundwater physical availability issue.
- Representative Cook further proposed that the Stakeholder Group be chaired by Pinal County Supervisor Stephen Miller and that Bill Garfield of Arizona Water Company and Jake Lenderking, Director of Water Resources at Global Water, serve as co-vice chairs.
- Representative Cook requested that the proposed leaders provide him with a roadmap for the Stakeholder Group.

Draft Priority Policy

- ADWR has prepared a draft priority policy substantive policy statement for stakeholder input.
- The draft policy establishes guidelines that could be used by Certificate applicants relying on a previously issued Analysis and Designation applicants relying on a previously issued Designation.
- The draft policy allows Certificate and Designation applicants relying on a previously issued Analysis or Designation to submit a hydrologic study or model run excluding Analyses issued after their previously issued Analysis or Designation.

Pending & Future Applications

- The 2019 Pinal AMA Model Run does not include new groundwater pumping for any pending applications.
- Given the significant volume of unmet demand for issued AWS determinations, it is unlikely that pending or future AWS applications can demonstrate physical availability of groundwater without significant changes in groundwater demands of existing uses and issued AWS determinations, new water supplies, and/or legal changes.

Process for Pending Applicants

- The 2019 Pinal AMA Model run does not demonstrate physical availability of groundwater for any pending AWS applications.
- Applicants may elect to have their applications remain pending while the stakeholder process progresses. ADWR will continue to extend the time period for demonstration of physical availability until further notice.

Process for Pending Applicants

- Applicants may seek to demonstrate physical availability of groundwater for pending applications, using ADWR's 2019 Pinal AMA model, subject to the existing requirements for groundwater modeling and AWS Rules.
- I recommend that applicants consult with ADWR prior to undertaking any modeling efforts.
- ADWR does not anticipate that modeling efforts are likely to be successful under the current circumstances.

Groundwater Redistribution Substantive Policy Statement

- On October 28, 2019, ADWR issued a substantive policy statement titled "Guidelines for Redistribution of Groundwater Pumping in Hydrologic Studies for Assured and Adequate Water Supply Applications."
- Provides guidance to assured and adequate water supply applicants seeking to geographically redistribute groundwater pumping in 100-year assured water supply groundwater model projections.
- This policy is applicable statewide inside and outside the AMAs.
- The policy can be found on ADWR's website at the following link:

  https://new.azwater.gov/sites/default/files/2019_10-28_AWS_8_Guidelines_for_Redistribution_of_Groundwater_Pumping_in_Hydro_Studies_for_AAWS_Applications.pdf

Questions?